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MATHEMATICS

CONCERNING THE RESOLVENTS OF AN HERMITIAN OPERATOR WITH THE DEFICIENCY-INDEX (m, m)

By M. KREIN

(Communicated by A. N. Kolmogoroff, Member of the Academy, 14. II. 1946)

In one of my preceding papers ([1]) I have indicated a method for obtaining all generalized resolvents R_z of an Hermitian operator A defined in the Hilbert space $\mathfrak{H}$ with a domain of definition $\mathfrak{D}(A)$ dense in $\mathfrak{H}$ and with the deficiency-index $(1,1)$*.

In the present note I generalize this result and find the general form of the resolvent R_z of an Hermitian operator A in the case where its deficiency-index is (m, m), m being an arbitrary natural number.

If the operator A is positive (*i. e.* $(Af, f) \geqslant 0$ for $f \in \mathfrak{D}(A)$), then for it there will be resolvents R_z, the whole spectrum of which is situated in the interval $(0, \infty)$; I determine also the general form of all these resolvents.

1. If the operator A has the deficiency-index (m, m), then for every non-real z the equation $A^*\varphi - z\varphi = 0$ (A^* being the operator maximally adjoined to A) will have exactly m (and not more) linearly independent solutions $\varphi_1(z), \varphi_2(z), \ldots, \varphi_m(z)$ which we shall construct in a special manner as vector-functions of z.

Let A^0 be a certain self-adjoined extension of the operator A, and $R_z^0 = (A^0 - zI)^{-1}$ $(\operatorname{Im} z \neq 0)$, the corresponding resolvent. Then the linearly independent solutions $\varphi_j(z)$ $(j = 1, 2, \ldots, m)$ of the equation $A^*\varphi - z\varphi = 0$, where z is an arbitrary non-real point, or even an arbitrary regular point of the resolvent R_z^0, may be constructed in such a way that for any two regular points z and ζ

$$\varphi_j(z) = \varphi_j(\zeta) + (z - \zeta) R_z^0 \varphi_j(\zeta) \quad (j = 1, 2, \ldots, m) \tag{1}$$

To this end for some $\zeta = \zeta_0$ $(\operatorname{Im} \zeta_0 \neq 0)$ we choose an arbitrary system of linearly independent solutions $\varphi_1^0, \ldots, \varphi_n^0$ of the equation $A_0^*\varphi - \zeta_0\varphi = 0$ and then putting in (1) $\zeta = \zeta_0$, $\varphi_j(\zeta_0) = \varphi_j^0$ $(j = 1, 2, \ldots, m)$ determine thence the $\varphi_i(z)$ $(j = 1, 2, \ldots, m)$ for every regular point z of the operator R_z.

Consider the matrix-function of the m-th order

$$Q(z) = \| q_{jk}(z) \|_1^m = \| ((z - z_0)\varphi_j(z) + iy_0\varphi_j(\bar{z}_0), \varphi_k(z_0)) \|_1^m$$

where $z_0 = x_0 + iy_0$ is an arbitrarily chosen regular point of the resolvent R_z.

By means of (1) it may be easily shown that the matrix-functions $Q(z)$ corresponding to different choices of the point z_0 can differ from one another only by an Hermitian matrix not depending on z.

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* Another solution of this problem was given by M. Neumark ([2]).

Denote by $\mathfrak{R}_m$ the class of all holomorphic in the upper half-plane $\operatorname{Im} z > 0$ matrix-functions $F(z) = \| f_{lk}(z) \|_1^m$ possessing the property that for any complex $\xi_1, \xi_2, \ldots, \xi_n$

$$\operatorname{Im}(\xi^* F(z)\xi) = \operatorname{Im}\left(\sum_{j,k=1}^{m} f_{jk}(z)\,\xi_k \bar{\xi}_i\right) \geqslant 0 \qquad (\operatorname{Im} z > 0)$$

It is easily seen that $Q(z) \in \mathfrak{R}_m$ and, moreover, that the Hermitian form $\operatorname{Im}(\xi^* Q(z)\xi)$ corresponding to it, is strictly positive for $\operatorname{Im} z > 0$.

Using the well-known integral representation of functions $f(z)$ holomorphic in and representing the upper half-plane on a part of it (cf., for instance [3], p. 52), we may obtain a general formula for an arbitrary matrix $F(z) \in \mathfrak{R}_m$. Denote by $\tilde{\mathfrak{R}}_m$ the class $\mathfrak{R}_m$ complemented by infinite matrix-functions $F(z)$ of the form

$$F(z) = S^* \begin{Vmatrix} G_p(z) & 0 \\ 0 & \infty\, I_q \end{Vmatrix} S \quad (p + q = m) \tag{2}$$

where $G_p(z)$ is a certain finite matrix-function from $\mathfrak{R}_p$: I_q, the unit matrix of order q; S, a non-singular numerical matrix of order m; and S^*, the matrix, Hermite adjoined to S.

If $F(z) \in \mathfrak{R}_m$ and for at least one $z\,(\operatorname{Im} z > 0)$ the Hermitian form $\operatorname{Im}(\xi^* F(z)\xi)$ is strictly positive, then the same will hold also for arbitrary $z\,(\operatorname{Im} z > 0)$; in this case the matrix $F(z)$ is non-singular and $-F^{-1}(z) \in \mathfrak{R}_m$.

Thus, if $F(z) \in \tilde{\mathfrak{R}}_m$, the matrix-function $(F(z) + Q(z))^{-1}\,(\operatorname{Im} z > 0)$ always exists. If $F(z)$ is of the form (2), then we shall put

$$(F(z) + Q(z))^{-1} = \lim_{t \to \infty} (F_t(z) + Q(z))^{-1} \qquad (\operatorname{Im} z > 0)$$

where $F_t(z)$ is obtained from $F(z)$ by replacing in (2) the symbol of infinity by t. This definition has always a sense and it will be readily found how this limit is calculated.

Recall now that by the spectral function of an operator A is understood [1,4] an one-parametric family $E(\lambda)$ $(-\infty < \lambda < \infty)$ of bounded self-adjoined operators, possessing the property that for any $f \in \mathfrak{H}$ $(E(\lambda)f, f)$ is a non-decreasing function of λ, $E(\lambda)f$ is a function of λ continuous from the left, $E(\lambda)f \to 0$ for $t \to -\infty$, and $E(\lambda)f \to f$ for $t \to \infty$ and, besides, for any $f \in \mathfrak{D}(A)$

$$(Af, Af) = \int_{-\infty}^{\infty} \lambda^2\, d(E(\lambda)f, f), \quad Af = \int_{-\infty}^{\infty} \lambda\, dE(\lambda) f$$

To the spectral function $E(\lambda)$ corresponds a certain generalized resolvent $R_z\,(\operatorname{Im} z > 0)$ of the operator A

$$R_z f = \int_{-\infty}^{\infty} \frac{dE(\lambda)f}{\lambda - z} \quad (f \in \mathfrak{H})$$

and the function $E(\lambda)$ is completely determined by R_z for $\operatorname{Im} z > 0$.

T h e o r e m 1. *The aggregate of all generalized resolvents R_z of the operator A is given by the formula* *

$$R_z = R_z^0 - \sum_{j,k=1}^{m} (\cdot, \varphi_j(\bar{z}))\, h_{jk}(z)\, \varphi_k(z) \quad (\operatorname{Im} z > 0) \tag{3}$$

* By $(\cdot, \varphi)\psi$, where $\varphi, \psi \in \mathfrak{H}$, we denote the operator correlating to every vector $f \in \mathfrak{H}$ the vector $(f, \varphi)\psi$.

where

$$\| h_{jk}(z) \|_1^m = (O(z) + F(z))^{-1}$$

and $F(z)$ *is an arbitrary matrix-function from the class* $\mathfrak{N}_m$.

Observe that formula (3) yields then and only then the resolvent R_z of a certain self-adjoined extension $\widetilde{A}$ of the operator A, when $F(z)$ is a constant Hermitian matrix.

2. Consider now the case where the Hermitian operator A is positive.

In this case, according to our preceding investigations (cf. ([5]), Theorem 2), the operator A possesses two positive self-adjoined extensions $A^{(\mu)}$ and $A^{(M)}$, the resolvents of which $R_z^{(\mu)}$ and $R_z^{(M)}$ possess the property that for any $a > 0$ and $f \in \mathfrak{H}$

$$(R_{-a}^{(\mu)} f, f) \leqslant (R_{-a} f, f) \leqslant (R_{-a}^{(M)} f, f)$$

where R_z is an arbitrary generalized resolvent of an operator with a non-negative spectrum. If $A^{(\mu)} = A^{(M)}$, then (and only then) the operator A possesses a unique positive self-adjoined extension, and, moreover, a unique resolvent R_z with a non-negative spectrum.

We shall be concerned with the case where $A^{(\mu)} \neq A^{(M)}$. This case holds if and only if (([5]), Theorem 3) among the solutions $\varphi (\neq 0)$ of the equation $A^*\varphi + \varphi = 0$ at least one belongs to the domain of values $\mathrm{Re}(A^{(\mu)})$ of the operator $A^{(\mu)}$.

Assuming, as before, that the deficiency-index of the operator A is (m, m), where m is a natural number *, let us construct in the manner indicated in the preceding section the systems of vector-functions $\varphi_1(z), \varphi_2(z), \ldots, \varphi_m(z)$ supposing hereby that $R_z^0 = R_z^{(\mu)}$. Without loss of generality we may assume that the vectors $\varphi_1(-1), \ldots, \varphi_p(-1)$ $(p \leqslant m)$ form the basis of the set of those solutions φ of the equation $A^*\varphi + \varphi = 0$ which belong to $\mathrm{Re}(A^{(\mu)})$.

Put then

$$P(z) = -z \lim_{\xi \uparrow 0} \| (\varphi_j(z), \varphi_k(-\xi)) \|_1^p .$$

It is easily shown that the limit of $P(z)$ exists for all non-positive z and that for all these z

$$P(z) = -z \left\| \int_0^\infty \frac{\lambda + a}{\lambda - z} \frac{d(E^{(\mu)}(\lambda)\varphi_j(-a), \varphi_k(-a))}{\lambda} \right\|_1^p \quad (a > 0)$$

where $E^{(\mu)}(\lambda)$ is a spectral function of the operator $A^{(\mu)}$.

The following theorem holds:

Theorem 2. *The aggregate of all generalized resolvents* R_z $(\mathrm{Im}\, z > 0)$ *possessing a non-negative spectrum of a positive operator* A *is given by the formula*

$$R_z = R_z^{(\mu)} - \sum_{j, k=1}^{p} (\,\cdot\,, \varphi_j(\bar{z}))\, h_{jk}(z)\, \varphi_k(z)\,, \tag{4}$$

where

$$\| h_{jk}(z) \|_1^p = (P(z) + F(z))^{-1}$$

and $F(z)$ *is an arbitrary matrix-function from the class* $\widetilde{\mathfrak{N}}_p$ *such that also* $zF(z) \in \widetilde{\mathfrak{N}}_p$.

---

* The assertions contained in n°2 were made under the assumption that A is an arbitrary positive Hermitian operator with a domain of definition dense in $\mathfrak{H}$.

Observe that the condition $zF(z) \in \mathfrak{N}_p$ for $F(z) \in \mathfrak{N}_p$ is equivalent to the fact that the matrix-function $F(z)$ is analytically continuable to the whole complex plane, intersecting the points of the positive real axis, and for $z = x\ (-\infty < x < \infty)$ turns into an Hermitian matrix, to which corresponds a non-negative Hermitian form. In particular, all these conditions are satisfied by the matrix $P(z) \in \mathfrak{N}_p$ for which the Hermitian form $\xi^* P(x) \xi\ (-\infty < x < 0)$ is strictly positive.

Observe also that the resolvent $R_z^{(\mu)}$ may be obtained by formula (4) for $F(z) \equiv 0$.

From Theorem 2 follows that if $p = 1$ (which is always the case when $m = 1$, $A^{(\mu)} \neq A^{(M)}$) then for any fixed z ($\mathrm{Im}\, z > 0$) and $f \in \mathfrak{H}$ the points of the complex plane w of the form $w = (R_z f, f)$, where R_z is an arbitrary generalized resolvent with a non-negative spectrum of an operator A, fill up a certain convex domain bounded by two circular arcs intersecting under the angle $\pi - \arg z$ (measured inside the domain).

Theorem 2 finds some interesting applications in the generalized problem of moments on a semi-axis [6] (of the Stieltjes type).

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MATHÉMATIQUES

SUR UNE FORMULE D'INVERSION

Par N. N. LEBEDEV

(Présenté par A. F. Joffé, de l'Académie, le 4. II. 1946)

Dans la présente Note nous établissons une formule analogue à celle de l'intégrale de Fourier

$$xf(x)=\frac{2}{\pi^2}\int_0^\infty K_{i\tau}(x)\,\tau\,\mathrm{sh}\,\pi\tau\,d\tau\int_0^\infty K_{i\tau}(\xi)\,f(\xi)\,d\xi \tag{1}$$

où $K_\mu(x)$ est la fonction cylindrique de Macdonald, $x>0$, $f(x)$ est une fonction arbitraire continue ainsi que sa dérivée et vérifiant la condition $x^2f(x)$, $xf'(x)\in L(0,\infty)$*.

Si l'on pose

$$\int_0^\infty f(x)\,K_{i\tau}(x)\,dx=F(\tau) \tag{2}$$

le théorème peut être écrit sous la forme d'une formule d'inversion

$$xf(x)=\frac{2}{\pi^2}\int_0^\infty K_{i\tau}(x)\,\tau\,\mathrm{sh}\,\pi\tau F(\tau)\,d\tau \tag{3}$$

qui donne pour chaque $x>0$ l'expression inverse de $f(x)$ au moyen de $F(\tau)$. Les formules d'inversion du type (2), (3) contenant une intégration suivant l'indice des fonctions cylindriques présentent un intérêt parce qu'elles sont liées à une classe de problèmes de la physique mathématique, étudiée par l'auteur en collaboration avec M. Kontorovitch. Dans un article précédemment publié (1) les auteurs donnent la démonstration d'une formule d'inversion, qui peut être considérée comme inverse par rapport au théorème de la présente Note, à savoir, ils démontrent que dans certaines conditions imposées à la fonction $F(\tau)$ l'égalité (3) entraîne l'égalité (2) **. Les applications diverses sont données dans les articles (2,3).

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* Les conditions imposées à $f(x)$ sont suffisantes, cependant le théorème peut subsister quand on considère des fonctions de classe plus générale.

** Dans nos notations ces conditions sont les suivantes:

(*i*) $F\left(\frac{\sigma+i\tau}{i}\right)$ est une fonction paire de la variable complexe $\mu=\sigma+i\tau$, holomorphe dans le domaine $-\delta\leqslant\sigma\leqslant\delta$ $(\delta>0)$.

(*ii*) $F\left(\frac{\sigma+i\tau}{i}\right)(\sigma+i\tau)\,e^{\frac{\pi|\tau|}{2}}\in L(-\infty,\infty)$.

(*iii*) $F\left(\frac{\sigma+i\tau}{i}\right)(\sigma+i\tau)\,e^{\frac{\pi|\tau|}{2}}\underset{|\tau|\to\infty}{\longrightarrow}0$ uniformément par rapport à σ pour $-\delta\leqslant\sigma\leqslant\delta$.

Pour démontrer le théorème remarquons qu'en vertu de $|K_{i\tau}(x)| \leqslant K_0(x)$* et $f(x)K_0(x) \in L(0, \infty)$ l'intégrale (2) converge uniformément par rapport à τ et présente une fonction continue de τ. L'intégrale

$$J(T, x) = \frac{2}{\pi^2}\int_0^T K_{i\tau}(x)\,\tau\,\mathrm{sh}\,\pi\tau\,F(\tau)\,d\tau \tag{4}$$

prise entre des limites finies, a donc un sens déterminé. Il faut démontrer que l'on a $\lim\limits_{T\to\infty} J(T, x) = x f(x)$. Substituons dans (4) l'intégrale (2) au lieu de $F(\tau)$. Comme la dernière intégrale converge uniformément, l'ordre d'intégration peut être changé

$$J(T, x) = \frac{2}{\pi^2}\int_0^\infty f(\xi)\,d\xi\int_0^T K_{i\tau}(x)K_{i\tau}(\xi)\,\tau\,\mathrm{sh}\,\pi\tau\,d\tau =$$

$$= x\int_{-\infty}^{\infty} f(xe^\theta)\,e^\theta G(x, \theta, T)\,d\theta \tag{5}$$

$$G = G(x, \theta, T) = \frac{2}{\pi^2}\int_0^T K_{i\tau}(x)\,K_{i\tau}(xe^\theta)\,\tau\,\mathrm{sh}\,\pi\tau\,d\tau \tag{6}$$

Les raisonnements qui suivent sont basés sur la représentation intégrale du produit des fonctions cylindriques

$$\frac{2}{\pi}K_\mu(x)\,K_\mu(xe^\theta)\sin\mu\pi = \int_{|\theta|}^{\infty} J_0\{xe^{\frac{\theta}{2}}(2\,\mathrm{ch}\,\alpha - 2\,\mathrm{ch}\,\theta)^{\frac{1}{2}}\}\,\mathrm{sh}\,\mu\alpha\,d\alpha \tag{7}$$

qui a lieu pour tous les μ vérifiant la condition $|R(\mu)| < {}^1/_4$. En tenant compte de (7) et en remarquant que pour $\mu = i\tau$ l'intégrale est uniformément convergente par rapport à τ** nous aurons

$$G = -\frac{1}{\pi}\int_{|\theta|}^{\infty} J_0\{xe^{\frac{\theta}{2}}(2\,\mathrm{ch}\,\alpha - 2\,\mathrm{ch}\,\theta)^{\frac{1}{2}}\}\,\frac{\partial}{\partial\alpha}\left(\frac{\sin\alpha T}{\alpha}\right)d\alpha \tag{8}$$

d'où

$$J(T, x) = -\frac{x}{\pi}\int_{-\infty}^{\infty} f(xe^\theta)\,e^\theta\,d\theta\int_{|\theta|}^{\infty} J_0(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\,\frac{\partial}{\partial\alpha}\left(\frac{\sin\alpha T}{\alpha}\right)d\alpha \tag{9}$$

où $\psi = 2\,\mathrm{ch}\,\alpha - 2\,\mathrm{ch}\,\theta$. Dans la suite les inégalités suivantes seront utiles

$$(i)\qquad \left|\frac{x}{\pi}f(xe^\theta)\,e^\theta J_0(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\,\frac{\partial}{\partial\alpha}\left(\frac{\sin\alpha T}{\alpha}\right)\right| \leqslant AT^2x^{\frac{1}{2}}\psi^{-\frac{1}{4}}e^{\frac{3\theta}{4}}\,|f(xe^\theta)|$$

$$(ii)\qquad e^{-\frac{\theta}{4}}\int_{|\theta|}^{\infty}\frac{d\alpha}{\psi^{\frac{1}{4}}} \leqslant B$$

* Cette inégalité résulte immédiatement de la représentation intégrale de $K_\mu(x)$ $K_\mu(x) = \int_0^\infty e^{-x\,\mathrm{ch}\,s}\,\mathrm{ch}\,\mu s\,ds$, qui est vraie pour toutes les valeurs de μ.

** Parce que le produit $x^{1/2}J_0(x)$ est borné pour $x \geqslant 0$ et $(2\,\mathrm{ch}\,\alpha - 2\,\mathrm{ch}\,\theta)^{-1/4} \in L(|\theta|, \infty)$.

où A et B sont des constantes absolues. L'inégalité (i) est une conséquence de ce que les fonctions $x^{\frac{1}{2}}J_0(x)$, $\cos x/x - \sin x/x^2$ sont bornées pour $x \geqslant 0$; l'inégalité (ii) se démontre facilement en faisant la substitution $\operatorname{ch}\alpha = y \operatorname{ch}\theta$. En vertu de ces inégalités nous trouvons l'évaluation

$$\frac{x}{\pi}\int_{-\infty}^{\infty}|f(xe^\theta)|\,e^\theta\,d\theta\int_{|\theta|}^{\infty}\left|J_0(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\frac{\partial}{\partial\alpha}\left(\frac{\sin\alpha T}{\alpha}\right)\right|d\alpha \leqslant$$

$$\leqslant CT^2x^{\frac{1}{2}}\int_{-\infty}^{\infty}|f(xe^\theta)|\,e^\theta\,d\theta = CT^2x^{-\frac{1}{2}}\int_0^{\infty}|f(\xi)|\,d\xi$$

C étant une constante absolue, d'où il résulte que l'intégrale double (9) converge absolument parce que $f(x)\in L(0,\infty)$. Donc, nous avons le droit de changer l'ordre d'intégration dans (9). Nous aurons *

$$J(T,x) = -\frac{x}{\pi}\int_0^{\infty}\frac{\partial}{\partial\alpha}\left(\frac{\sin\alpha T}{\alpha}\right)d\alpha\int_{-\alpha}^{\alpha}f(xe^\theta)\,e^\theta J_0(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\,d\theta =$$

$$= \frac{x}{\pi}\int_0^{\infty}\omega(\alpha)\frac{\sin\alpha T}{\alpha}\,d\alpha \qquad (10)$$

$$\omega(\alpha) = \frac{1}{2}f(xe^\alpha)\,e^\alpha + \frac{1}{2}f(xe^{-\alpha})\,e^{-\alpha} + \frac{1}{2}\int_{-\alpha}^{\alpha}f(xe^\theta)\,e^\theta\frac{\partial J_0}{\partial\alpha}(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\,d\theta \qquad (11)$$

La démonstration du théorème (1) se réduit maintenant à la démonstration de la possibilité d'appliquer la formule classique de l'intégrale de Dirichlet à la fonction $\omega(\alpha)$. Comme $\omega(\alpha)$ est continue et possède une dérivée continue dans chaque intervalle fini, il reste à démontrer que $\omega(\alpha)\in L(0,\infty)$.

Pour le démontrer il faut utiliser l'identité

$$\frac{\partial J_0}{\partial\alpha}(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}}) = \frac{\partial J_0}{\partial\theta}(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}}) - \frac{xe^{\frac{3\theta}{2}}}{\psi^{1/2}}(1-e^{-\alpha-\theta})\,J_1(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})$$

et exclure la dérivée par rapport à θ au moyen d'intégration par parties

$$\omega(\alpha) = f(xe^\alpha)\,e^\alpha - \frac{1}{2}\int_{-\alpha}^{\alpha}[f(xe^\theta)\,e^\theta +$$

$$+ xe^{2\theta}f'(xe^\theta)]\,J_0(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})\,d\theta - \frac{x}{2}\int_{-\alpha}^{\alpha}e^{5\theta/2}(1-e^{-\alpha-\theta})\,f(xe^\theta)\,\frac{J_1(xe^{\frac{\theta}{2}}\psi^{\frac{1}{2}})}{\psi^{1/2}}\,d\theta$$

d'où, en tenant compte de ce que les fonctions $x^{1/2}J_0(x)$, $x^{-\frac{1}{2}}J_1(x)$ sont bornées pour $x \geqslant 0$, on obtient

$$|\omega(\alpha)| \leqslant |f(xe^\alpha)|\,e^\alpha + \frac{D}{x^{1/2}}\int_{-\alpha}^{\alpha}[\,|f(xe^\theta)|\,e^\theta +$$

$$+ xe^{2\theta}|f'(xe^\theta)|\,]\,e^{-\frac{\theta}{4}}\frac{d\theta}{\psi^{1/2}} + Ex^{\frac{3}{2}}\int_{-\alpha}^{\alpha}|f(xe^\theta)|\,e^{\frac{11\theta}{4}}\frac{d\theta}{\psi^{1/4}} \qquad (12)$$

* La partie tout intégrée s'annule parce que $|J_0(x)| \leqslant 1$ et $f(x)\in L(0,\infty)$.

où D, E sont des constantes absolues. Il suit maintenant de (12), (ii)

$$\int_0^\infty |\omega(\alpha)|\, d\alpha \leqslant \int_0^\infty |f(xe^\alpha)|\, e^\alpha\, d\alpha + \frac{BD}{x^{1/2}} \int_{-\infty}^{\infty} \left[|f(xe^\theta)|\, e^\theta + xe^{2\theta}\, |f'(xe^\theta)| \right] d\theta +$$

$$+ BDx^{\frac{3}{2}} \int_{-\infty}^{\infty} |f(xe^\theta)|\, e^{3\theta}\, d\theta \leqslant a(x) \int_0^\infty |f(\xi)|\, d\xi +$$

$$+ b(x) \int_0^\infty |f'(\xi)|\, \xi\, d\xi + d(x) \int_0^\infty |f(\xi)|\, \xi\, d\xi$$

où $a(x)$, $b(x)$, $c(x)$ sont bornées pour $x > 0$. Comme $f(x)$, $x^2 f(x)$ et $x f'(x) \in L(0, \infty)$, on a $\omega(\alpha) \in L(0, \infty)$.

En appliquant le théorème de Dirichlet, nous aurons

$$\lim_{T \to \infty} J(T, x) = x\, \omega(0) = x f(x) \tag{13}$$

ce qui démontre le théorème énoncé.

Exemple 1. La fonction $f(x) = e^{-x \cos \alpha}$ $(0 \leqslant \alpha < \pi/2)$ vérifie les conditions du théorème (1). Il résulte de la formule

$$F(\tau) = \int_0^\infty e^{-x \cos \alpha} K_{i\tau}(x)\, dx = \frac{\pi}{\operatorname{sh} \pi\tau} \frac{\operatorname{sh} \alpha\tau}{\sin \alpha}$$

que l'on a

$$x \sin \alpha\, e^{-x \cos \alpha} = \frac{2}{\pi} \int_0^\infty \tau \operatorname{sh} \alpha\tau\, K_{i\tau}(x)\, d\tau \tag{14}$$

Exemple 2. De l'inégalité

$$\int_0^\infty e^{-a^2 x^2} K_{i\tau}(x)\, dx = \frac{\sqrt{\pi}\, e^{\frac{1}{8a^2}}}{4a \operatorname{ch} \frac{\pi\tau}{2}} K_{\frac{i\tau}{2}}\left(\frac{1}{8a^2}\right)$$

il résulte

$$xe^{-a^2 x^2} = \frac{e^{\frac{1}{8a^2}}}{4\sqrt{\pi}\, a} \int_0^\infty K_{i\tau}(x)\, K_{\frac{i\tau}{2}}\left(\frac{1}{8a^2}\right) \tau \operatorname{sh} \frac{\pi\tau}{2}\, d\tau. \tag{15}$$

Institut de Physique Appliquée
à Léningrad.
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MATHÉMATIQUES

SUR LES ÉQUATIONS, SYSTÈMES D'ÉQUATIONS SEMI-JACOBIENS, SEMI-JACOBIENS GÉNÉRALISÉS AUX DÉRIVÉES PARTIELLES DE PREMIER ORDRE A PLUSIEURS FONCTIONS INCONNUES

Par G. PFEIFFER, de l'Académie des Sciences de l'Ukraine

Les relations

$$\Phi_i(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-1}) = 0 \qquad (1)$$
$$i = 1, 2, \ldots, k$$

$\Phi_1, \ldots, \Phi_k$ — fonctions arbitraires des arguments

$$\varphi \equiv \varphi(z_1, \ldots, z_k, x_1, \ldots, x_n, c_1, \ldots, c_h) \qquad (2)$$

$$\frac{D(\Phi_1, \Phi_2, \ldots, \Phi_k)}{D(z_1, z_2, \ldots, z_k)} \neq 0 \qquad (3)$$

avec

$$c_1, c_2, \ldots, c_h \qquad (4)$$

paramètres, présentent l'intégrale générale du système Jacobien

$$\begin{array}{c} X_1 p_{11} + \ldots + X_n p_{1n} = Z_1 \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ X_1 p_{k1} + \ldots + X_n p_{kn} = Z_k \end{array} \qquad (5)$$

$$Z_i = (-1)^{i-1} \frac{D(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-1})}{D(z_1, \ldots, z_{i-1}, z_{i+1}, \ldots, z_k, x_1, \ldots, x_n)}$$

$$X_j = (-1)^{k+j-1} \frac{D(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-1})}{D(z_1, \ldots, z_k, x_1, \ldots, x_{j-1}, x_{j+1}, \ldots, x_n)}$$

l'intégration duquel est équivalente à l'intégration de l'équation linéaire homogène

$$Z_1 \frac{\partial f}{\partial z_1} + \ldots + Z_k \frac{\partial f}{\partial z_k} + X_1 \frac{\partial f}{\partial x_1} + \ldots + X_n \frac{\partial f}{\partial x_n} = 0 \qquad (6)$$

Eliminant les paramètres (4) des équations (5), on obtient si

$$h = k - 1 \qquad (7)$$

une équation

$$f(x_\alpha, z_\gamma, p_{\alpha\delta}) = 0 \qquad (8)$$

et si

$$h = k - m, \quad m > 1 \qquad (9)$$

un système d'équations

$$f_\lambda(x_\alpha, z_\lambda, p_{\alpha\tau}) = 0 \qquad (10)$$
$$\lambda = 1, 2, \ldots, m$$

Appelons l'équation (8) semi-Jacobiens. Les relations

$$\Phi_i(\varphi_1, \ldots, \varphi_l, \varphi_{k+1}, \ldots, \varphi_{k+n-r}) = 0 \qquad (11)$$
$$i = 1, 2, \ldots, k, \quad r > 1$$

$\Phi_1, \ldots, \Phi_k$ — fonctions arbitraires des arguments,

$$\varphi = \varphi(z_1, \ldots, z_k, x_1, \ldots, x_n, c_1, \ldots, c_h) \qquad (12)$$
$$\frac{D(\Phi_1, \Phi_2, \ldots, \Phi_k)}{D(z_1, z_2, \ldots, z_k)} \neq 0 \qquad (13)$$

avec

$$c_1, c_2, \ldots, c_h \qquad (14)$$

paramètres présentent l'intégrale générale du système Jacobien généralisé

$$\begin{gathered}
X p_{1j} + X_1^j p_{11} + \ldots + X_{n-r}^j p_{1,n-r} = Z_1^j \\
\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots \\
X p_{kj} + X_1^j p_{k1} + \ldots + X_{n-r}^j p_{k,n-r} = Z_k^j \qquad (15) \\
j = n-r+1, \ldots, n
\end{gathered}$$

$$Z_\nu^j = (-1)^{\nu-1} \frac{D(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-r})}{D(z_1, \ldots, z_{\nu-1}, z_{\nu+1}, \ldots, z_k, x_1, \ldots, x_{n-r}, x_j)}$$

$$X_\mu^j = (-1)^{k+\mu-1} \frac{D(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-r})}{D(z_1, \ldots, z_k, x_1, \ldots, x_{\mu-1}, x_{\mu+1}, \ldots, x_{n-r}, x_j)}$$

$$X = (-1)^{k+n-r} \frac{D(\varphi_1, \ldots, \varphi_k, \varphi_{k+1}, \ldots, \varphi_{k+n-r})}{D(z_1, \ldots, z_k, x_1, \ldots, x_{n-r})}$$

dont l'intégration est équivalente à l'intégration du système d'équations linéaires homogènes

$$Z_1^j \frac{\partial f}{\partial z_1} + \ldots + Z_k^j \frac{\partial f}{\partial z_k} + X_1^j \frac{\partial f}{\partial x_1} + \ldots + X_{n-r}^j \frac{\partial f}{\partial x_{n-r}} + X \frac{\partial f}{\partial x_j} = 0 \qquad (16)$$
$$j = n-r+1, \ldots, n$$

Eliminant les paramètres (14) des équations (15) on obtient si

$$h = kr - 1 \qquad (17)$$

une équation

$$f(x_\alpha, z_\gamma, p_{\alpha\tau}) = 0 \qquad (18)$$

et si

$$h = kr - m, \quad m > 1 \qquad (19)$$

un système d'équations

$$f_\lambda(x_\alpha, z_\lambda, p_{\alpha\tau}) = 0 \qquad (20)$$
$$\lambda = 1, 2, \ldots, m$$

Appelons l'équation (18) et le système (20) semi-Jacobiens généralisés.

L'application de la méthode spéciale d'intégration [1] aux équations (8), (18), aux systèmes d'équations (10), (20), consiste en deux règles suivantes.

La première règle

En cherchant sur l'équation (8), sur le système d'équations (10), le système Jacobien (5), on trouve que ses coefficients dépendent de $h = k - 1$, $h = k - m$ paramètres. Regardant ces paramètres comme constantes arbitraires et intégrant l'équation linéaire homogène (6), on recevra l'intégrale générale (1) de l'équation (8), du système d'équations (10).

La deuxième règle

En cherchant sur l'équation (18), sur le système d'équations (20) le système Jacobien généralisé (15), on trouve que ses coefficients dépendent de $h = kr - 1$, $h = kr - m$ paramètres. Ayant déterminé ces paramètres comme fonctions des variables et des h constantes arbitraires essentielles de telle manière que le système d'équations linéaires homogènes (16) soit complet, on recevra, en intégrant le système (16), l'intégrale générale (11) de l'équation (18), du système d'équations (20).

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FLUID DYNAMICS

ON THE LAW OF RESISTANCE IN THE CASE OF TURBULENT FLOW THROUGH SMOOTH TUBES

By A. N. KOLMOGOROFF, Member of the Academy

In place of the well-known type of formula for the coefficient of resistance ζ

$$\frac{1}{\sqrt{\zeta}} = A \lg (\mathrm{Re}\sqrt{\zeta}) + B \tag{1}$$

which has come into general use from Kármán's classical works, Konakov, in a note recently published in this periodical [1], suggests formulae of the type

$$\frac{1}{\sqrt{\zeta}} = A \lg \mathrm{Re} + B \tag{2}$$

From his treatment of the measurements made by Nikuradze Konakov has been led to propose the following values for the coefficients in (2)

$$\frac{1}{\sqrt{\zeta}} = 1.8 \lg \mathrm{Re} - 1.5 \tag{3}$$

This result invites comparison with the formula

$$\frac{1}{\sqrt{\zeta}} = 2.0 \lg (\mathrm{Re}\sqrt{\zeta}) - 0.8 \tag{4}$$

proposed by Nikuradze for the best approximation of his experimental data within the range of Reynolds numbers he has investigated (from 3070 to 3 230 000).

For 125 measurements carried out by Nikuradze the mean quadratic deviation from theoretically computed values is nearly the same whether formula (3) or (4) is used. In both cases it will be found to equal 0.07. Nor shall we detect any significant advantage of one of these formulae over the other if we were to consider large and small Reynolds numbers separately and subject the experimental data to a thorough analysis. Therefore it is rather difficult to understand the reason which made Konakov express himself in favour of his formula, as regards its applicability to a wide range of

Reynolds numbers. Perhaps he compared it not with formula (4), but with another formula of Nikuradze

$$\frac{1}{\sqrt{\xi}} = 1.95 \lg (\mathrm{Re} \sqrt{\xi}) - 0.55 \tag{5}$$

which, however, had been recommended by its author for large Reynolds numbers only.

Still, it must be admitted that formulae of type (2) are easier to use. Within the accuracy of the available observations they may indeed from purely empirical point of view claim equality with formulae of type (1). On this consideration the contribution of Konakov may be only well-comed. Unfortunately, his paper pretends to give a theoretical deduction of formula (2). From his belief in the theoretical soundness of this formula the author arrives at the conclusion that it should be used in extrapolating to higher Reynolds numbers, and with this one can hardly agree. It will be shown presently that his reasoning, if correctly completed, would only have led Konakov to the generally adopted formula (1).

Let us start from Konakov's formulae

$$\frac{W_\delta}{W} = \sqrt{\frac{\xi}{4(2N+\sigma)}}\left(1 - 2\frac{\delta}{d_0}\right) \tag{13}$$

$$\frac{1}{\sqrt{\xi}} - \frac{[4(2N+\sigma)]^{3/2}}{8} = N \ln \frac{W_\delta d_0}{\nu} + \frac{\sigma}{3} \tag{19}$$

where N and σ are constants. The quantity

$$1 - 2\frac{\delta}{d_0}$$

is very close to unity. So we need not treat it as a variable (its variability was neglected also by Konakov). Accordingly, the expressions (13) and (19) may be written as follows

$$\frac{W_\delta}{W} = c_1 \sqrt{\xi} \tag{6}$$

$$\frac{1}{\sqrt{\xi}} = c_2 \ln \frac{W_\delta d_0}{\nu} + c_3 \tag{7}$$

It will be obvious that after W_δ is determined from (6) and substituted in (7) we shall obtain a formula of type (1). Instead of doing so Konakov assumed

$$\frac{W_\delta}{W} = \mathrm{const} \tag{8}$$

and after substituting in (7) the value of W_δ derived from this relation he arrived at (2). However, within the range of Reynolds numbers considered by him $\sqrt{\xi}$ varies rather widely, its highest value being twice as large as its lowest (see the drawing adjoined to his note). And according to formula (6) or (13) the variation of the ratio W_δ/W is just as wide, too.

Therefore the use of (6) instead of (8) is beyond one's comprehension.

It may be remarked, in addition, that the assumption

$$\frac{W_\delta}{W} = \mathrm{const}$$

together with (13), leads to

$$\zeta = \frac{\text{const}}{1 - 2\frac{\delta}{d_0}}$$

or, with good approximation, to the equality

$$\zeta = \text{const} \tag{9}$$

This is what we have in rough tubes, for which the hypothesis of similarity of the flow at different Reynolds numbers («automodelling») holds throughout the cross-section of the tube. But in the case of smooth tubes its range of application is confined to *relative velocities* at different points of the «turbulent core» of the flow.

It will be apparent that Konakov's considerations go only to confirm the theoretical soundness of formula (1) for large Reynolds numbers. Not until Reynolds numbers shrink to thousands or tens of thousands, can we expect to meet with deviations from this formula.

Indeed, the experimental data of Nikuradze seem to indicate that the real plot of $1/\sqrt{\zeta}$ as a function of $\lg(\mathrm{Re}\sqrt{\zeta})$ is a straight line only for large Re, and shows a slight downward bent for small Re. It is to be regretted that the advantage that may be gained in using for large Re formula (5), which is built on the experimental indication just mentioned, instead of formula (4), which satisfactorily interpolates the observation throughout the range of variation of Re, lies too close to the limits of experimental error. If, however, the downward bent of the curve should be real, it can certainly receive no theoretical explanation on the basis of the fallaceous constructions made by Konakov.

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ASTRONOMY

ON THE LAW OF PLANETARY DISTANCES

By O. J. SCHMIDT, Member of the Academy

1. The distances from planet to planet increase as we move away from the Sun. Is this variation of distance subject to mathematical law, and if it is, just what is the underlying physical reason? The question has long attracted the attention of astronomers. Well-known is «Bode's law», which was made public in 1772. In terms of the distance between the Earth and the Sun (put at unity) the distance from the Sun to Mercury is approximately 0.4, and the distances to the other planets, according to Bode's law, are expressed by the formula $0.4+0.3.2^n$, where n is the number of the planet ($n=0$ for Venus, $n=1$ for the Earth, and so on). In the table below the figures obtained according to Bode are compared with the actual distances:

	Mercury	Venus	Earth	Mars		Jupiter	Saturn	Uranus	Neptune	Pluto
Bode's law . . .	0.4	0.7	1	1.8	2.6	5.2	10.0	19.6	38.8	77.2
Actual distance .	0.39	0.72	1	1.52	...	5.20	9.54	19.19	30.07	39.5

In many cases the coincidence is striking, indeed. But there are also considerable departures. We find no planet between Mars and Jupiter, though the law requires that one should be present there. The asteroids fill the gap badly, for their total mass is far less than that of any individual planet. Unsatisfactory also is the figure for Neptune, and if we refer it to Pluto in order to obtain a better coincidence, we will find it even more difficult to explain why the little Pluto should be admitted to full membership in the series, when much the more massive Neptune is excluded from it.

For close on two centuries Bode's law has continued to be a subject of discussion. Some scientists considered it a law of nature, unaccounted-for but none the less real. Others (their number appears to be stronger) looked upon it as a chance coincidence of two sequencies of numbers. Recently Weizsäcker (1) has made an attempt to deduce Bode's law in a simplified form by approximately doubling the distance on transition from one planet to the next. But the premises on which his conclusion is based seem very artificial.

Nor is it all that can be said against Bode's law. Its most essential drawback is that the planets are arranged in a single row without taking account of the fact that they actually fall into two sharply different groups. It is in fact an important feature of the solar system that Jupiter and the planets farther away from the Sun are of much larger mass, compared to the nearer

planets—from Mercury to Mars—not to speak of other differences between these groups. One may hardly expect that an adequate law of planetary distances can be based on the neglect of this distinction.

The author's theory of the origin of planets ([2]) yields a reasonable interpretation at once of the existence of two groups of planets, and of the distance relationships *within each group separately*.

First, we shall consider the qualitative aspect of the problem, then proceed to its quantitative treatment, and, lastly, compare the results of the theory with the known facts.

2. On the author's theory the planets have arisen from a swarm of meteorites captured once by the Sun, while it was crossing the central plane of the Galaxy. Afterwards, as a result of collisions, smaller meteorites settled on those of larger mass, thus contributing to the eventual formation of several large bodies, the planets.

Let us examine this process in greater detail. The relatively large nuclei of the future planets, which had segregated at the early stages of the process, must, on account of symmetry, have been revolving in the central plane of the swarm along circular orbits. Collision between such a nucleus and a meteorite occurs when the meteorite which may move in an elliptical as well as circular orbit happens to arrive at its node in the central plane just mentioned at the time that the nucleus is also there ([3]). Adding its mass to that of the planetary nucleus, the meteorite also imparts to it its angular momentum of revolution about the Sun. Thus, the angular momentum of a planet is the sum of the angular momenta of the meteorites of which it is composed, and the position of its orbit (its distance from the Sun) is determined by the value of this total angular momentum. All the time mutual perturbations make the meteorites slightly change their orbits, and the neighbour meteorites come to fill the place of those «scooped out» by the planets.

Let us see now what is likely to happen in the natural course of events to two neighbouring planet nuclei that are in progress of growth. If close to each other, they will soon exhaust the store of meteorites that stand a chance to get between them. With no meteorites to be captured from these quarters, the nuclei, provided they do not fuse together, will further increase in mass and momentum at the expense of meteorites from outside of the exhausted interval. This means that one of the planets will now aggregate meteorites revolving nearer to the Sun, and accordingly, having smaller angular momenta in the mean, as compared to the meteorites that will add to the other planet. As a result, the angular momentum per unit mass will gradually decrease in one planet, and increase in the other, and the difference between their orbital radii will grow correspondingly. This will continue until the planet is drawn into the region where it will have to compete with its neighbour from the other side, which will exert upon it an opposite influence. It appears therefore that the planetary distances have been controlled by the mechanism of the planet growth from meteorites. A mathematical treatment of the results of this control will be given in § 4.

3. Before we proceed to it we shall dwell on the fate of the planets initiated in the neighbourhood of the Sun. In capturing meteorites such a planet had to compete not only with its neighbour farther away from the Sun, but with the Sun itself. Certainly, it was no match for the latter. The major part of the meteorites was bound to fall to the Sun and not to the planet on account of two factors. First, owing to perturbations, part of the meteorites may have assumed orbits with perihelion distances shorter than the Sun's radius, and such meteorites were destined to fall to the Sun on the next revolution. Secondly, the pressure of Sun light made the particles of matter gradually lose their orbital momentum ([4]) with the result that numbers of meteorites approached the Sun in a spiral, and eventually fell upon it. The magnitude of this effect (time of approach) depends on the size of the particle and its initial distance from the Sun.

It will be obvious that the influence of the two factors was particularly strong on meteorites revolving in the vicinity of the Sun. The fall of these meteorites, as will be shown elsewhere, is responsible for the rotation of the Sun on its axis. So in the region about it the Sun itself came in for by far the bigger share of the meteorites present and thus prevented their formation into bodies of respectable size. From the remains of the meteoric mass in the proximity to the Sun only small planets could arise, and the first planet whose mass corresponded to the total mass of the meteorites revolving in its domain could only be formed at a distance from the Sun, where the influence of the above-mentioned factors was so weakened as not to affect the result materially.

This is the reason why we have to-day two groups of planets: the so-called terrestrial planets, not very different from the Earth in size, and the major (distant) planets of much larger dimensions.

4. We are going now to derive a law of planetary distances from the theory. To begin with, let us consider the major planets, to wich we shall assign numbers in order of distance from the Sun, putting $n=0$ for Jupiter.

The total angular momentum of the system rests invariable, though individual meteorites may gain or lose momentum by mutual approach. Of course, small changes are more probable than great. At this juncture the law of distribution of these probabilities is of no import to us, and it will suffice to assume that increase and decrease in angular momentum by the same amount are equally probable.

We shall speak of domains of meteorites belonging to particular planets and of the boundaries between these domains as of definite notions. For an individual meteorite the chances are in favour of its being brought in the end on to that particular planet whose angular momentum per unit mass differs least from that which the meteorite had upon the formation of the meteoric swarm about the Sun. Together, all the meteorites whose angular momenta in this sense are nearest to the angular momentum of an n-th planet will be described as the «domain of the n-th planet». A meteorite which stands equal chances to fall to the n-th or to the $(n+1)$-th planet is said to be the boundary between the domains of these planets. As a matter of fact, all meteorites of a domain do not necessarily fall to the planet controlling this domain. Some may land on an alien planet. But as their own planet is also likely to capture some meteorites from foreign domains, there will be a tendency to equalize the balance, and we may assume, for the sake of simplification, that every planet will in time receive all the meteorites revolving in its domain, and no others. Neither shall we take account of the small angle that may possibly exist between different momentum vectors, so that they might be added arithmetically.

No further simplification is required for the mathematical deduction of the law.

Let u_n be the angular momentum per unit mass of the n-th planet and m_n the total mass of the meteorites in the respective domain. The angular momentum of the meteorite revolving at the boundary between the domains n and $n+1$ will be denoted by u'_n. The mass of an individual meteorite will be expressed as a diferential dm, and its angular momentum per unit mass will be denoted by u. Then, in virtue of the law of conservation of angular momentum, we can write the following expression for the total angular momentum in the domain n

$$u_n m_n = \int_{u=u'_{n-1}}^{u=u'_n} u\, dm \qquad (1)$$

By the definition of the boundary, the angular momentum u'_n differs from u_n just as much as from u_{n+1}, *i. e.*

$$u_{n+1} - u'_n = u'_n - u_n$$

or

$$u'_n = \frac{u_n + u_{n+1}}{2} \tag{2}$$

The paper cited above ([2]) contains a deduction of the relation

$$a = \frac{\rho}{2}\frac{1+e}{1-e} \tag{3}$$

which connects the semi-major axis of the orbit with its eccentricity e for every meteorite captured by the Sun. For the meaning of the quantity ρ (the limit distance at which capture occurs) the reader is referred to that paper. Here it will suffice to mention that ρ may taken to be constant in the mean throughout the meteoric swarm. In the cited paper it was shown also that e in this formula can be used with $+$ as well as with $-$ sign, and that all its values from -1 to $+1$ are equally probable. In virtue of the latter circumstance the mass of meteorites with e ranging from e_1 to e_2 is proportional to the magnitude of this interval. If the total mass of the swarm be denoted by m, we shall have

$$dm = \frac{m}{2}\, de \tag{4}$$

because the interval of variation of e from -1 to $+1$ equals two. For any member of the system the angular momentum per unit mass is known to be

$$k\sqrt{M}\sqrt{a(1-e^2)} \tag{5}$$

where M is the mass of the Sun, k^2 is the constant of gravitation. Let us so select the units as to have $k\sqrt{M}=1$. For an n-th planet moving in a circular orbit at a distance R_n from the Sun the angular momentum per unit mass is $\sqrt{R_n}$.

For the angular momentum u of a meteorite we have, by (3) and (5), the expression

$$u = \sqrt{a(1-e^2)} = \sqrt{\frac{\rho}{2}}\,(1+e) \tag{6}$$

Denoting eccentricity of the boundary meteorite orbit by e'_n we have respectively

$$u'_n = \sqrt{\frac{\rho}{2}}\,(1+e'_n) \tag{7}$$

Making use of the formulae (4) to (7), we can rewrite the equality (1) as follows

$$u_n m_n = \int_{e'_{n-1}}^{e'_n} \sqrt{\frac{\rho}{2}}(1+e)\,\frac{m}{2}\,de$$

or, after integration,

$$u_n m_n = \frac{m}{2}\sqrt{\frac{\rho}{2}}\;\frac{(1+e'_n)^2-(1+e'_{n-1})^2}{2} \tag{8}$$

On the other hand, by virtue of (4),

$$m_n = \frac{m}{2}(e'_n - e'_{n-1}) \tag{9}$$

From (8) and (9) follows

$$u_n = \sqrt{\frac{\rho}{2}\,\frac{(1+e'_n)+(1+e'_{n-1})}{2}}$$

i. e.

$$u_n = \frac{u'_{n-1}+u'_n}{2} \tag{10}$$

Hence using (2) in order to express u'_{n-1} and u'_n through the angular momenta of the planets, we get

$$u_n = \frac{u_{n-1}+u_{n+1}}{2}$$

And as $u_n = \sqrt{R_n}$ for the planets, therefore

$$\sqrt{R_n} = \frac{\sqrt{R_{n-1}}+\sqrt{R_{n+1}}}{2} \tag{11}$$

This equality can be written also in the form

$$\sqrt{R_{n+1}} - \sqrt{R_n} = \sqrt{R_n} - \sqrt{R_{n-1}} \tag{12}$$

To put it into words:

The difference between the square roots of their distances from the Sun is a constant for any pair of successive planets.

This theorem involves the law of planetary distances, as derived from the author's theory. We can, in fact, denote $\sqrt{R_0}$ by a, and the constant difference between the successive square roots by b, to obtain

$$\boxed{\sqrt{R_n} = a + bn} \tag{13}$$

which means that *the square roots of the distances between the successive planets and the Sun form an arithmetical progression.*

This is precisely the author's law of planetary distances. We have derived it for the distant planets, *i. e.* for the region where the direct absorption of meteorites by the Sun, discussed in § 3, is a factor of minor importance. The following considerations will show, however, that it holds also for the nearer planets. In the course of time the Sun had absorbed the main mass of smaller particles from the region of the nearer planets, so that only those of relatively larger size remained, and their orbits were less sensitive to the influence of light pressure. Moreover, once the meteorites with the longest orbits had fallen to the Sun, the remaining orbits, being more circular, were also less liable to be affected by perturbations. Therefore the action of the two factors mentioned in § 3 was growing weaker as time went on, and eventually the conditions were created for planets to form from the remains of meteoric matter in the regions lying nearer to the Sun. On this consideration we may expect the above theorem and the law of planetary distances, as expressed by formula (13), to hold for the nearer planets as well, though, of course, with modified coefficients a and b.

5. Let us compare our conclusions with the actual data (the values of R are given in astronomical units).

	Jupiter		Saturn		Uranus		Neptune		Pluto
R	5.20		9.54		19.19		30.07		39.52
$\sqrt{R}$	2.28		[illegible].09		4.38		5.48		6.29
$\sqrt{R_{n+1}} - \sqrt{R_n}$ . . .		0.81		1.29		1.10		0.81	

From the figures of the last row the square root differences appear to be not strictly constant. Yet they fluctuate within a rather narrow range about a mean value equal to 1.00. We may look upon this coincidence as satisfactory, for the law only expresses the average tendency in the action of millions of meteorite falls, the process which has not even come to an end as yet.

We shall now compare the law $\sqrt{R_n} = a + bn$ with actual data. For a we take the actual value of $\sqrt{R_0}$ for the first planet of the series (Jupiter), and for b the mean value of the differences $\sqrt{R_{n+1}} - \sqrt{R_n}$, *i. e.* 1.00.

Table 1

	Jupiter	Saturn	Uranus	Neptune	Pluto
$\sqrt{R}$ theoret.	2.28	3.28	4.28	5.28	6.28
$\sqrt{R}$ actual	2.28	3.09	4.38	5.48	6.29
R theoret.	5.20	10.76	18.32	27.88	39.44
R actual	5.20	9.54	19.19	30.07	39.52
Departure	0	+13%	— 5%	— 7%	0

Here, in contrast to Bode's law, Neptune and Pluto comply with the general rule.

Let us turn to the nearer planets. For them the actual differences $\sqrt{R_{n+1}} - \sqrt{R_n}$ are

0.23 0.15 0.23

the mean value being 0.20. The actual and theoretical figures are brought together in Table 2.

Table 2

	Mercury	Venus	Earth	Mars
$\sqrt{R}$ theoret.	0.62	0.82	1.02	1.22
$\sqrt{R}$ actual	0.62	0.85	1.00	1.23
R theoret.	0.39	0.67	1.04	1.49
R actual	0.39	0.72	1.00	1.52
Departure	0	— 7%	+ 4%	— 2%

Institute of Theoretical Geophysics.
Academy of Sciences of the USSR.

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PHYSIQUE

ABSORPTION DES ONDES ULTRA-ACOUSTIQUES DANS LES MÉLANGES ALCOOL MÉTHYLIQUE—EAU ET ALCOOL ÉTHYLIQUE—EAU

Par I. G. MIKHAILOV et S. B. GOUREVITCH

(Présenté par A. N. Terenin, de l'Académie, le 18. III. 1946)

On sait que dans certains mélanges binaires liquides le coefficient d'absorption des ondes ultra-acoustiques dépend de la concentration et possède un maximum bien exprimé. Ce phénomène a été trouvé, par exemple, par Bazhulin et Merson dans le mélange acétone—eau (1).

Un des auteurs de la présente Note a trouvé que l'absorption des ondes ultra-acoustiques croît pour certaines concentrations dans un mélange alcool éthylique—eau (2). Dans la présente Note nous donnons les résultats des mesures quantitatives du coefficient d'absorption dans les mélanges alcool méthylique—eau et alcool éthylique—eau*.

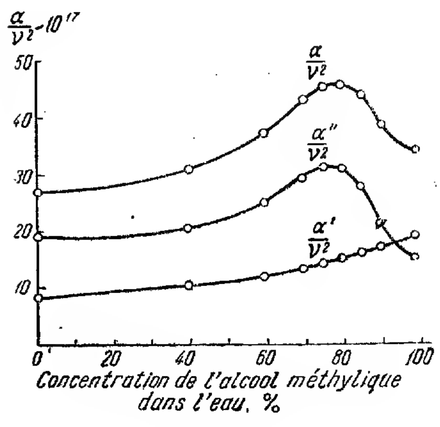

Fig. 1.

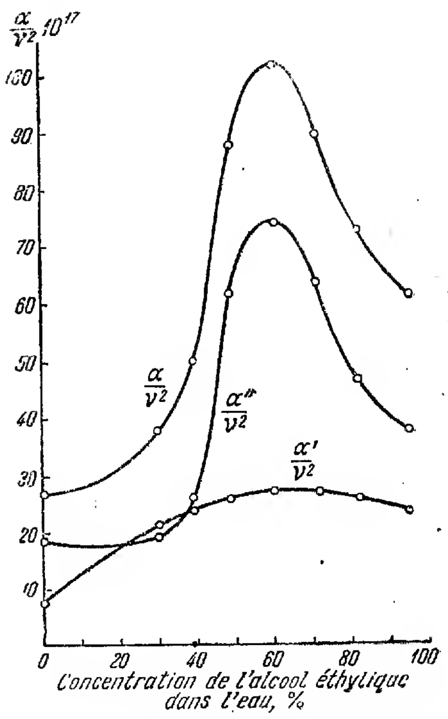

Fig. 2.

* Lorsque ces mesures ont été terminées, nous avons appris de P. A. Bazhulin, qu'après la publication de notre communiqué (2), des mesures analogues ont été effectuées par J. M. Merson, tombé sur le champ de bataille. Malheureusement, ces résultats n'ont pas été publiés.

Les mesures ont été effectuées par une méthode mécanique. L'on observait les déviations d'une ailette d'aluminium, qu'elle subissait sous l'action de la pression sonore. Celles-ci étaient mesurées au moyen d'un microscope avec un oculaire à micromètre. Bien que cette méthode soit simple, son utilisation doit être suivie de certaines précautions afin d'obtenir de résultats satisfaisants. Nous communiquons plus bas des résultats qui sont encore préliminaires; actuellement nous effectuons l'expérience destinée à augmenter l'exactitude des mesures.

Les résultats des mesures de α/ν^2 pour les mélanges indiqués sont donnés dans le tableau et sur les fig. 1 et 2. Ils se rapportent à la fréquence 12970 kHz et à la température 18°C. Le coefficient d'absorption α est calculé pour l'amplitude en cm^{-1}. La concentration est volumétrique. On voit que les deux mélanges possèdent un maximum bien net qui est fonction de la concentration.

Alcool méthylique—eau					Alcool éthylique—eau				
P. c. volumétrique	α	$\frac{\alpha}{\nu^2}\cdot 10^{17}$	$\frac{\alpha'}{\nu^2}\cdot 10^{17}$	$\frac{\alpha''}{\nu^2}\cdot 10^{17}$	P. c. volumétrique	α	$\frac{\alpha}{\nu^2}\cdot 10^{17}$	$\frac{\alpha'}{\nu^2}\cdot 10^{17}$	$\frac{\alpha''}{\nu^2}\cdot 10^{17}$
0	0.046	27	8	19	0	0.046	27	8	19
39	0.053	31	10.5	20.5	30	0.065	38	21	17
59	0.063	37	12.0	25.0	39	0.085	50	24	26
69	0.073	43	13.5	29.5	49	0.150	88	26	62
74	0.076	45	14	31.0	60	0.173	102	27.5	74.5
79	0.078	46	15	31.0	71	0.155	91	27	64
84	0.075	44	16	28	82	0.124	73	26	47
89	0.065	38	17	21	95	0.105	62	24	38
98	0.058	34	19	15					

Dans le mélange alcool méthylique—eau les deux composants possèdent les coefficients d'absorption à peu près égaux et le mélange a un maximum d'absorption aux environs de 80 pour cent. Le coefficient d'absorption pour l'alcool éthylique est deux fois plus grand que pour l'eau. Le maximum du mélange a lieu pour la concentration 60 pour cent.

Dans le tableau et sur les figures sont également données les valeurs calculées par la formule de Stockes en tenant compte de la viscosité ordinaire. Si l'on tient encore compte de la viscosité volumétrique, l'équation de l'absorption prend la forme

$$\frac{\alpha}{\nu^2}=\frac{2\pi^2}{\rho v^3}\left(\frac{4}{3}\eta+\eta'\right)=\frac{\alpha'}{\nu^2}+\frac{\alpha''}{\nu^2}$$

(en négligeant la correction de Kirchhoff sur l'absorption due à la conductibilité thermique).

La différence des ordonnées α/ν^2 et α'/ν^2 permet de calculer la part de l'absorption α''/ν^2 due à la viscosité volumétrique.

On voit sur les fig. 1 et 2 que le caractère de variation de l'absorption α/ν^2 est déterminé par la variation de α''/ν^2 en fonction de la concentration. Il en résulte que la viscosité volumétrique joue un rôle principal dans l'absorption des ondes ultra-acoustiques dans les mélanges indiqués.

Institut de physique de
l'Université de Léningrad.

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PHYSIQUE

THE OPTICAL AND PHOTOELECTRICAL PROPERTIES OF ANTIMONY-CAESIUM CATHODES

By N. D. MORGULIS

(Communicated by S. I. Vavilov, Member of the Academy, 8. I. 1946)

One of the most interesting sets of questions connected with the problem of modern effective photoelectric cathodes-electron emitters which are known to be of a semi-conductor nature—is that of the conditions determining the absorption of light quanta by these emitters, the excitation of photoelectrons, and the kinetics of their subsequent motion towards the emitter surface. The present investigation is devoted to these problems, the well-known antimony-ceasium, Sb—Cs, photocathode being selected as the object of study. The experimental results presented below are as yet of a preliminary character.

Given a wedge-shaped cathode with a continuously varying thickness d, admitting both direct illumination, *i. e.* ordinary illumination from the anode side of the photocell, and reverse illumination, *i. e.* from the outer side of the glass bulb covered with the Sb—Cs layer; let us assume that we have here a purely volume photoeffect, and that the absorption by the emitters of both light quanta and excited photoelectrons obeys the exponential law

$$n_q = n_{q_0} e^{-\mu d}, \quad N_e = N_{e0} e^{-\sigma d} \tag{1}$$

where μ and σ are the absorption coefficients of the quanta and the photoelectrons, respectively. Accepting this law for photoelectrons means assuming that their absorption results from a single act of adhesion to the crystal lattice and not from the gradual loss of their energy.

Thus, from assumption (1) it is easy to show that the intensity of the photoelectronic current with direct illumination I_1 depends on the thickness of the photocathode d and the coefficients μ and σ in the following way

$$I_1 = A \frac{\mu}{(\mu+\sigma)} \left[1 - e^{-(\mu+\sigma) d}\right] \tag{2}$$

i. e. as d decreases, the direct photocurrent I_1 gradually approaches a maximum, limiting, value which (for $d \gg 1/(\mu+\sigma)$ is equal to

$$I_{1m} = A \frac{\mu}{(\mu+\sigma)} \tag{3}$$

On the other hand, the intensity of the photoelectronic current with reverse illumination I_2 will, under the same conditions, show the following dependence

$$I_2 = A \frac{\mu}{(\mu-\sigma)} \left[e^{-\sigma d} - e^{-\mu d}\right] \tag{4}$$

i. e. the reverse photocurrent I_2 will have its maximum I_{2m} at a certain definite thickness of the layer equal to

$$d_m = \frac{\ln \mu/\sigma}{(\mu - \sigma)} \tag{5}$$

These formulae may be utilized for the solution of our problem, which is the determination of the values of μ and σ for various wave-lengths λ of the light irradiating the photocathode; whence we may determine the values of $1/\mu$ and $1/\sigma$ which characterize the thickness of the zone where the main absorption of the incident radiation occurs ($1/\mu$) and of the zone from which the excited photoelectrons emerge ($1/\sigma$).

In our study, for instance, the value of μ was determined from (1) by measuring the absorption curve of light quanta at various thickness d; the value of σ was then determined from (5) according to the position of the maximum reverse photocurrent I_{2m}.

In order to carry out those measurements, special photocells were prepared. On their walls a layer of antimony in the shape of a long wedge tapering to a point was deposited by means of evaporation from a sphere made of the metal concerned. This layer was then completely exposed to caesium vapour until an antimony-caesium layer was obtained having normal photo-electronic sensitivity throughout its surface. Contact with the Sb—Cs photolayer was obtained by means of two platinized strips placed parallel to the Sb—Cs wedge on either side. In this manner we obviated the distorting effect of the longitudinal resistance of the Sb—Cs layer. Since the source of the antimony was a small sphere, the subsequent distribution of the thickness of the antimony layer along our wedge and, accordingly, the distribution of the thickness of the Sb—Cs layer (making the natural assumption that the distension of the antimony layer under caesium vapour treatment is uniform) may be expressed, as can be readily shown, in the following form

$$d = \frac{M}{4\pi a^2 \rho} \cdot \frac{1}{[1 + (x/a)^2]^{3/2}} = \frac{d_0}{[1 + (x/a)^2]^{3/2}} \tag{6}$$

The value of the constant d_0 may be determined for the Sb—Cs layer by employing some other independent methods. The author, for instance, utilized the fact, established for the first time in our laboratory by P. G. Borzyak, that the ordinary interference picture may be observed in thin Sb—Cs layers. In our case, on observing this picture in reflected monochromatic light, in the direction of the rise in the value of d from its smallest values, we first see the continuous bright edge of the wedge, passing subsequently into the ordinary sequence of dark and bright interference bands. Hence, it follows that the index of refraction n of the Sb—Cs layer lies within limits of $n_0 > n > 1$ where n_0 is the index of refraction of glass, for reflection from the anterior and posterior surfaces of the Sb—Cs layer occurs here with similar phase; since in our case $n_0 \approx 1.52$, we assume $n \approx 1.4$. Hence the thickness of the Sb—Cs layer d_k in the position of the k-th dark interference band is *

$$d_k = (2k - 1)\frac{\lambda}{4n} \quad \text{where } k = 1, 2, 3, \ldots \tag{7}$$

Our chief measurements included the determination of the distribution of the optical transparency D, the direct I_1 and the reverse I_2 photocurrents along our wedge-shaped Sb—Cs cathode with various wave-lengths of the incident monochromatic radiation λ = 630, 560, 490 and 420 mμ obtained by means of a Leiss monochromator. The relative intensity of the investigat-

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* The questions of the precise determination of the value of n and of the effect of the absorption by the Sb—Cs layer on the position of the interference bands, are deferred for the present.

ed radiation in measurements of the transparency of Sb—Cs layer was determined by means of a blocking-layer sulphur-silver photocell for $\lambda = 630$ and 560 mμ, and by means of a vacuum Sb—Cs photocell for $\lambda = 490$ and 420 mμ.

The preliminary results of the measurements of the values D, I_1 and I_2 obtained in this manner, for our lamp No. 3, for example, are presented in

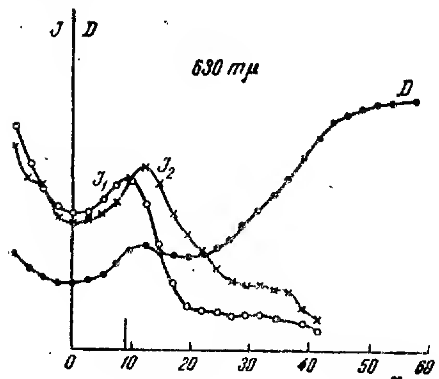

Fig. 1.

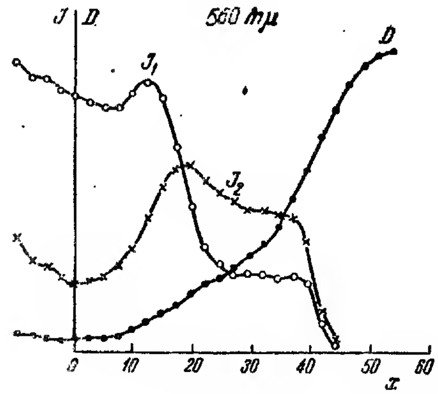

Fig. 2.

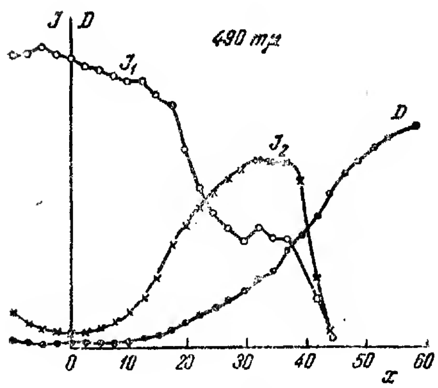

Fig. 3.

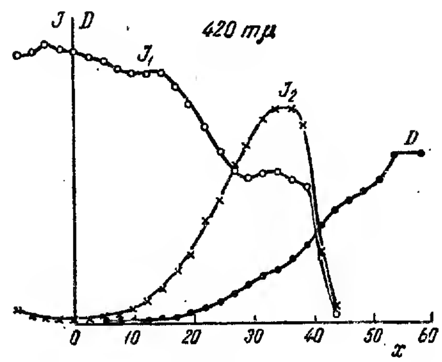

Fig. 4.

Figs. 1, 2, 3, and 4 for four wave-lengths λ. The results of computations of formulae (1) and (5) using these measurements are presented in the table.

λ, mμ	μ, cm^{-1}	$1/\mu$, cm	d_m, Å	σ, cm^{-1}	$1/\sigma$, cm
630	$8.4 \cdot 10^5$	$1.2 \cdot 10^{-5}$	1100	$1.0 \cdot 10^5$	$1.0 \cdot 10^{-5}$
560	$1.5 \cdot 10^5$	$6.7 \cdot 10^{-6}$	740	$1.5 \cdot 10^5$	$6.7 \cdot 10^{-9}$
490	$2.7 \cdot 10^5$	$3.7 \cdot 10^{-6}$	350	$3.1 \cdot 10^5$	$3.2 \cdot 10^{-6}$
420	$4.1 \cdot 10^5$	$2.4 \cdot 10^{-6}$	250	$4.2 \cdot 10^5$	$2.4 \cdot 10^{-6}$

A study of these data leads to the following conclusions.

1. The relative slope of the curves of transparency and, consequently, the value of the coefficient of absorption μ, as well as the mean opaque zone of the cathode, increase with a decrease in the wave-length λ.

2. In Fig. 1 with $\lambda = 630$ mμ we observe at $x = 12.5$ the appearance of some local maximum, which vanishes for other wave-lengths. This shows that this phenomenon can hardly be attributed to any optical or structural properties of our Sb—Cs film at the given place. In the same figure, the line shows the position of the first dark interference band.

3. The direct photocurrent I_1, contrary to expectation, does not always yield a monotonous change with a variation in the value of d; with increase in λ and, especially, at $\lambda = 630$ mμ an anomalous character for the changes in the value of I_1 is observed, the reasons for which are not yet clear. It is interesting to note that, for undiscovered reason, this anomaly of the direct photocurrent seems to parallel the anomaly of the optical transparency mentioned above.

4. In complete agreement with expectation, the reverse photocurrent I_2 behaves perfectly normally at all wave-lengths λ and passes through a maximum at the values of d_m given in the table. These values of d_m diminish with a decrease in the wave-length of radiation.

5. With a decrease in the value of d the values of both photocurrents I_1 and I_2 approach—as follows from (2) and (4)—the same values, which is evidence of the fact that here $d \ll 1/\mu$ and $d \ll 1/\sigma$ and that the direction of the initial velocities of the excited electrons are isotropically along and against the direction of the incident radiation.

6. The absolute values of $1/\mu$ and $1/\sigma$ prove to be—as can be seen from the table—of the order of 100—1000 Å and diminish with a decrease in the wave-length λ. The last result for the value of $1/\sigma$ proves to be somewhat unexpected, for one might have expected that with a decrease in λ, *i. e.* with increase in quantum energy and, consequently, in the initial energy of the excited photoelectrons, the value of $1/\sigma$ would rise rather than decrease. This result may, therefore, be best explained by the plausible assumption that the Sb—Cs emitter possesses several levels, variously disposed, from whence electrons are detached. At any rate, a final explanation of this essential question must be referred to the future.

The investigation described in the foregoing was carried out in May — June 1941 under the collaboration of P. G. Borzyak.

Institute of Physics.
Academy of Sciences of the Ukrainian SSR.
Kiev.

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PHYSIQUE APPLIQUÉE

TRANSMISSION DE LA CHALEUR PAR UN TUBE CYLINDRIQUE ET UNE SPHÈRE DANS LE COURANT DE GAZ

Par Z. F. TCHUKHANOV, membre correspondant de l'Académie

La transmission de la chaleur par la surface d'un tube cylindrique dans un courant transversal d'un liquide (ou d'un gaz) a une importance considérable dans les sciences thermiques appliquées modernes. Malheureusement, presque toutes les études que nous connaissons et qui sont consacrées à cette question, celles d' Antouffiev et Kozatchenko (1), de Mikheev et Eigenson (2) et d'autres savants, sont bornées à un traitement empirique des données expérimentales dans la forme des critériums de similitude.

Parmi les tentatives peu nombreuses d'analyse théorique de la transmission de chaleur par un cylindre (5) dans le courant transversal aux conditions réelles, le plus grand intérêt présente sans doute l'étude de Kroujiline (4), qui a donné l'équation de la transmission de la chaleur par la partie frontale du cylindre.

Le caractère d'un courant rencontrant un cylindre a été objet d'un grand nombre d'études (6). Il a été établi que pour les valeurs de Re, s'étendant à tout le domaine qui présente un intérêt pratique (jusqu'à Re $\sim$ 200 000), la couche frontière est (dans les conditions normales) laminaire près de la partie frontale du cylindre. Le courant subit toute une série de transformations derrière le cylindre, lorsque la valeur de Re change; ainsi, pour Re d'ordre 0.5—1.5 on observe un courant qui longe rigoureusement la surface du cylindre, puis le courant se détache de la surface du cylindre, et il se forme derrière le tube de «tourbillons (6) laminaires»; ceux-ci ne passent, probablement, en tourbillons développés que pour Re $>$ 1000. Le détachement des tourbillons de la surface cylindrique a lieu pour Re $\sim$ 30—50. Il est tout naturel que le caractère du mouvement influe sur la transmission de la chaleur du cylindre au courant.

Il est évident que la transmission de la chaleur dans la partie frontale du cylindre doit satisfaire dans les conditions normales (jusqu'à Re $\sim$ 100 000) à l'équation correspondant à une couche frontière laminaire, comme celle de Kroujiline (4), par exemple. Afin de l'appliquer pour les buts pratiques il faut savoir la variation de δ en fonction de x.

Pour le cylindre et un courant isothermique, Pohlhausen a obtenu les données (7) pour δ le long du contour du cylindre $d = 9.75$ cm, qui a été étudié expérimentalement par Himentz pour $w_0 = 19$ cm/sec et Re $\cong$ 18.500. En utilisant ces résultats nous pouvons obtenir les courbes théoriques de l'intensité de l'échange de chaleur de la partie frontale du cylindre. Les courbes calculées de cette façon sont présentées sur la fig. 1 pour les valeurs différentes de Re; de même on y a donné le changement de B_x suivant le contour du cylindre dans l'équation

$$\mathrm{Nu} = Bx \cdot \mathrm{Re}^{0.5} \tag{1}$$

On voit que la coïncidence des courbes théoriques avec l'expérience sur la fig. 1 est plus que satisfaisante. Après l'intégration on obtient pour la partie frontale du cylindre l'équation

$$\overline{Nu} = 0.8 \cdot Re^{0.5} \tag{2}$$

Lorsque l'angle d'attaque du courant change, l'équation (2) changera de même car la forme du contour longé par le courant sera modifiée. On peut approximativement* tenir compte de ce changement par le changement

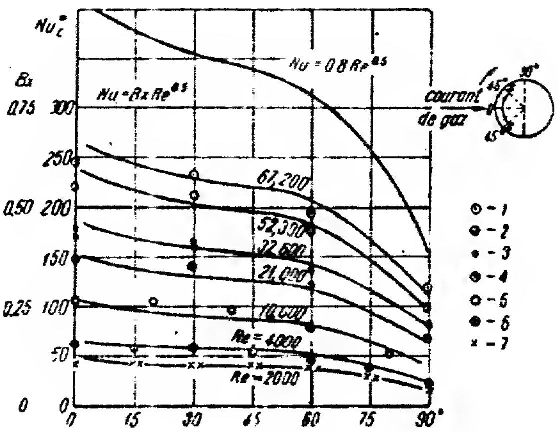

Fig. 1. La variation de l'intensité de la transmission de la chaleur suivant le contour du cylindre. Les courbes en lignes continues sont tracées d'après l'équation théorique de Kroujiline. Les données expérimentales: *1* — Kroujiline et Schwab, Re = 67 200; *2* — mêmes auteurs, Re = 52 300; *3* — mêmes auteurs, Re = 32 600; *4* — mêmes auteurs, Re=21 000; *5*—Klein, Re=10 000; *6*—Joukovsky, Kiréev et Chamchéev, Re= 4000; *7*—mêmes auteurs, Re= 2000.

respectif de la grandeur caractéristique. Sur la fig. 2 nous donnons la courbe théorique correspondante, ainsi que les résultats respectifs de l'expérience.

Mais quel est alors le caractère de la transmission de la chaleur de la «poupe» du cylindre dans les conditions de formation des tourbillons? Le domaine du détachement progressif du courant de la surface du cylindre jusqu'au moment de formation d'un couple de tourbillons dépend de la diminution de Nu par rapport à sa valeur donnée par (2), par suite de l'exclusion d'une partie de la surface du cylindre de la zone de transmission active de la chaleur.

A partir de Re ∼ 30—50 jusqu'à Re ∼ 5000—10 000 s'établit une relatiton plus au moins constante entre la partie frontale (∼45 pour cent de la surface cylindrique totale) et la «poupe» (∼55 pour cent de la surface). L'équation (2) donne la définition de l'intensité du processus pour la partie frontale.

Le mouvement du courant près de la «poupe» avec des tourbillons «laminaires» a lieu avec la vitesse constante suivant le contour du cylindre. Pour cela, en cas où le couple de tourbillons enveloppe toute la surface (55 pour cent), on peut, probablement avec une exactitude suffisante, utiliser pour cette partie du cylindre l'équation de la transmission de la chaleur d'une plaque en régime laminaire. Or, l'étude des photographies de mouvement du

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* Pour la résolution exacte du problème il faut tenir compte du changement du caractère du courant, car grâce à ceci le «nouveau profil» n'est plus cylindrique. Cela a une importance surtout pour les petits angles d'attaque, lorsque le courant rencontrant transversalement un seul cylindre passe en courant longeant une «plaque».

courant montre, que l'on a en outre du couple principal de tourbillons, des tourbillons supplémentaires, situés entre ceux-ci et le point de leur détachement. Ce phénomène ne permet pas de déterminer la valeur théorique exacte du coefficient pour Re dans l'équation générale de l'échange de la chaleur du cylindre avec un courant gazeux. Mais la forme de l'équation correspond à (2)

$$\mathrm{Nu} = 0.8 \cdot 0.45\,\mathrm{Re}^{0.5} + b \cdot 0.55\,\mathrm{Re}^{0.5} = a\,\mathrm{Re}^{0.5} \tag{3}$$

La valeur de b et aussi de a peut être déterminée, si l'on sait celle de Nu pour une seule valeur de Re. La courbe de la fig. 3 nous donne pour Re$=1000$, $a \cong 0.5$. Donc la transmission de la chaleur du cylindre pour Re de

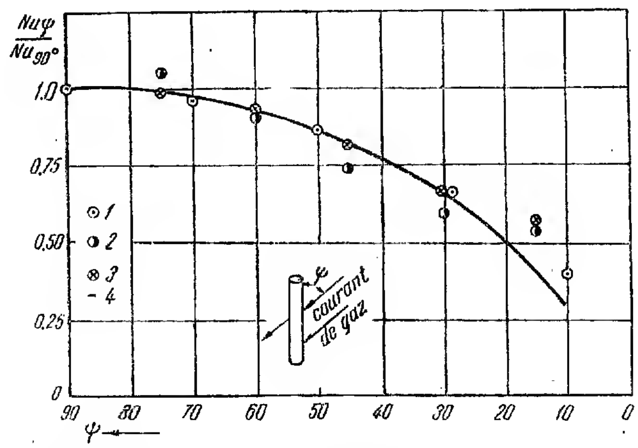

Fig. 2. La variation de l'intensité de la transmission de la chaleur par un cylindre en fonction de l'angle d'attaque: *1*—les expériences de Lokchine et Ornatsky; *2*—celles de Sinelnikov et Tchachikhine; *3*—celles de Fornem; *4*—la courbe théorique.

50 à $\sim$10 000 (fig. 3) montre que la coïncidence obtenue avec l'expérience est suffisamment bonne.

Pour le domaine de Re$=$10 000—100 000, présentant le plus grand intérêt au point de vue pratique, lorsque le courant se meut suivant la «poupe» du cylindre avec des tourbillons développés, l'équation de la transmission de la chaleur peut être obtenue de la façon analogue à celle de (3). Dans ce but il suffit de déterminer l'équation relative à la «poupe» du cylindre pour les conditions définies. Tant comme dans le cas des tourbillons «laminaires», la transmission de la chaleur de la «poupe» en cas des tourbillons développés sera décrite par l'équation relative au courant gazeux longeant une plaque avec une couche frontière turbulente.

Comme nous avons établi [8], cette équation* a la forme suivante:

$$\mathrm{Nu}_x^* \approx 0.022\,\mathrm{Re}_x^{0.82} \tag{4}$$

Par conséquent, l'équation de la transmission de la chaleur d'un cylindre situé dans un courant transversal pour le domaine Re$=$10 000—100 000 se présentera sous la forme

$$\mathrm{Nu} = 0.8 \cdot 0.45\,\mathrm{Re}^{0.5} + c\,\mathrm{Re}^{0.82} \tag{5}$$

---

* Pour une plaque on obtient une approximation plus grande (après intégration) $\overline{\mathrm{Nu}}_x \approx 0.026\,\mathrm{Re}_x^{0.82}$.

La détermination théorique de c, de même que de b dans l'équation (3), présente un problème indépendant et suffisamment complexe par lui même. Dans notre cas c est définie par la valeur connue de Nu (pour Re donné). Alors l'équation (5) s'écrit

$$Nu = 0.36\, Re^{0.5} + 0.070\, Re^{0.82} \quad (6)$$

Cette équation est précisément celle de la transmission de la chaleur d'un cylindre dans le domaine Re = 10 000—100 000.

Dans le domaine dit «subcritique», où a lieu la turbulence de la couche frontière de la partie frontale du cylindre, l'équation ne contiendra qu'un

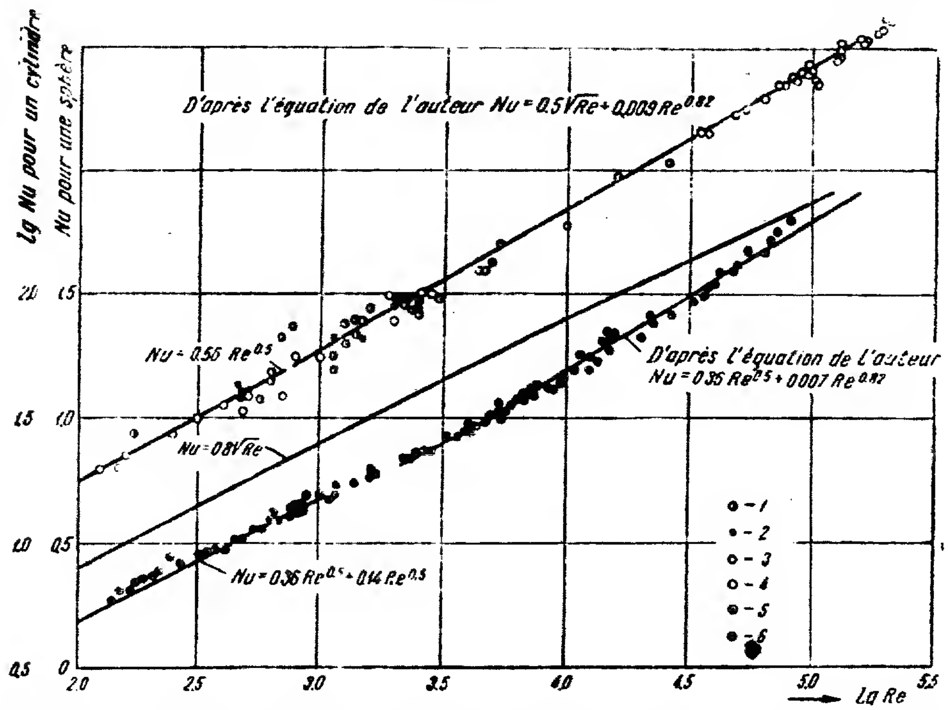

Fig. 3. La transmission de la chaleur par une parcelle sphérique et cube: 1—les expériences de Liakhovsky avec des boules fixes d'acier d=2.43—14.84 mm; 2—celles de Liakhovsky avec des cubes fixes d'acier d=6.15 mm; 3—celles de Loytzansky et Schwab avec une boule d=70 et 150 mm; 4—celles de Vyrouboff avec une boule. La transmission de la chaleur par un cylindre dans un courant gazeux transversal: 5—les expériences de Hilpert avec des tubes normaux; 6—celles d'Eigenson, même cas.

seul membre avec Re à la puissance ~0.82. L'équation de la transmission de la chaleur par une sphère a une forme pareille:

$$Nu = 0.50\, Re^{0.5} + 0.09\, Re^{0.82} \quad (7)$$

Sur la fig. 3 est donnée la comparaison des résultats que nous avons obtenus au moyen des équations déduites, avec ceux de l'expérience.

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PHYSICAL CHEMISTRY

ON THE BURNING OF ASH COAL. II

By V. I. BLINOV

(Communicated by N. P. Chizhevsky, Member of the Academy, 11. II. 1946)

1. The rate of burning of ash coal depends essentially on temperature. It is important therefore to establish what temperature a burning coal will have under given conditions, and how it will change as the process of combustion develops. These problems are discussed in the present paper.

The distribution of temperature is assumed to be steady at every particular instant, and it is also supposed that the coal, when burnt out, leaves a layer of ash, at the boundary of which the combustion takes place and through which heat is transferred by conduction. The delivery of heat from the coal is supposed to obey Newton's law.

There will be deduced the relations determining the temperature in the zone of burning for a wall, a cylinder and a sphere.

2. A wall of ash coal is taken to be bounded by parallel planes. In its middle lies the origin of coordinates, the x-axis being directed perpendicular to the planes bounding the wall. Denote the total thickness of the wall and the thickness of its unburnt part by $2d$ and 2ζ, respectively; the absolute temperature in the zone of burning, at the external surface of the wall and in the surrounding gas medium, by T_w, T_0' and T_0; the termal conductivity of the ash layer by λ; the heat conductance by α; the specific rate of combustion by k_s; the thermal effect of the reaction by q.

The temperature distribution in the ash layer should satisfy the differential equation

$$\frac{d^2T}{dx^2}=0 \tag{1}$$

under the boundary conditions

$$qk_s=-\lambda\left(\frac{dT}{dx}\right)_{x=\zeta}, \quad -\lambda\left(\frac{dT}{dx}\right)_{x=d}=\alpha\,(T_0'-T_0) \tag{2}$$

From equation (1) and condition (2) follows

$$qk_s=\alpha_0\,(T_w-T_0) \tag{3}$$

where

$$\alpha_0=\alpha\frac{1}{1+\mathrm{Nu}\,(1-\xi)}, \quad k_s=\frac{kc_0}{1+H+A\,(1-\xi)} \tag{4}$$

$$\mathrm{Nu}=\frac{\alpha d}{\lambda}, \quad \xi=\frac{\zeta}{d}, \quad k=k_0e^{-E/RT}, \quad H=\frac{k}{\alpha_d}, \quad A=\frac{kd}{D}$$

Here k is a constant of the rate of reaction between coal and oxygen; E is activation energy; R is the universal gas constant; α_d is a coefficient characterizing the rate of outward diffusion and analogous to heat

conductance in Newton's law; D is the coefficient of oxygen diffusion through the ash layer; and c_0 is the concentration of oxygen in the gas medium surrounding the wall. The ratio defining k_s is taken from an earlier work [1].

It is from equation (3) that we can determine the temperature at which combustion will take place in a wall of ash coal at a steady state.

3. Let us now consider an ash coal cylinder of radius r_0. The radius of the unburnt part of the cylinder will be denoted by r_1.

In this case the computations lead to a relationship identical with formula (3) except that now

$$\alpha_0 = \frac{\alpha}{\xi(1 - \mathrm{Nu}\ln\xi)}, \quad k_s = \frac{kc_0}{1 + H\xi - A\xi\ln\xi} \tag{5}$$

$$\mathrm{Nu} = \frac{\alpha r_0}{\lambda}, \quad A = \frac{kr_0}{D}, \quad \xi = \frac{r_1}{r_0}$$

4. Relation (3) is also true for a sphere, but here we have

$$\alpha_0 = \frac{\alpha}{\xi} \frac{1}{\xi + \mathrm{Nu}(1 - \xi)}, \quad k_s = \frac{kc_0}{1 + H\xi^2 + A\xi(1 - \xi)} \tag{6}$$

the quantities Nu, A and ξ are determined in the same way as in the case of a cylinder.

5. Equation (3) may as well be solved by the graphical method formerly used by the author [2].

On the x-axis of a rectangular system of coordinates we lay off T_w, and on the y-axis, $z_1 = qk_s$, $z_2 = \alpha_0(T_w - T_0)$ (Fig. 1). The abscissae of the intersection points of the curves thus plotted will give the values of the temperature that becomes established under the given conditions.

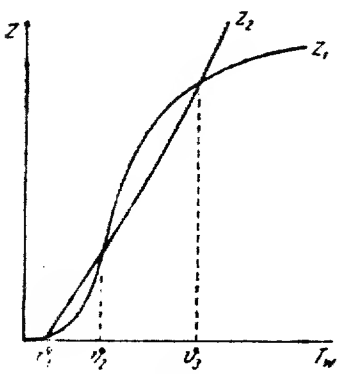

Fig. 1.

According to the conditions under which the process goes on, the curves z_1 and z_2 intersect at one or at three points. In the former case one definite state of combustion is possible; in the latter, three states, corresponding to three values of the temperature, ϑ_1, ϑ_2 and ϑ_3.

At $T_w = \vartheta_1$ the process is slow and stable (oxidation), at $T_w = \vartheta_3$ it is stable and proceeds rapidly (burning). But at $T_w = \vartheta_2$ the process will not be stable. If in fact the temperature has risen above ϑ_2, the balance of heat is positive, more heat being received than lost, and the temperature in the burning zone will increase until it reaches the point ϑ_3 when the coal bursts into flame. On the other hand, if the temperature remains below ϑ_2, the balance of heat is negative, and the temperature will decrease down to ϑ_1, at which point the process of combustion dies out. Therefore ϑ_2 is the minimum temperature to which under given conditions the coal must be heated up in order to start burning. In other words, ϑ_2 is the inflammation temperature of the coal.

6. As the zone of reaction shifts, z_1 and z_2 do not remain invariable, and accordingly the values ϑ_1, ϑ_2 and ϑ_3 vary also. The portion of z_1 corresponding to lower temperatures will not be affected by the variation of ξ. In the case of a burning wall the upper portion of the curve declines continuously as the burning zone moves, while in the case of a sphere or cylinder it either goes up all the time, or down at first to rise later in accordance with the ratio of H to A.

The curve z_2 will not change in shape, but the angle γ between z_2 and the x-axis will decrease continuously with ξ in the case of a wall, while it will either grow all along or decrease at first and increase later in the case of a sphere or cylinder.

If z_1 and z_2 intersect at three points, ϑ_2 will decrease with γ and approach ϑ_1. Under certain conditions ϑ_2 will coincide with ϑ_1, and the coal in the process of oxidation will burst into flame spontaneously.

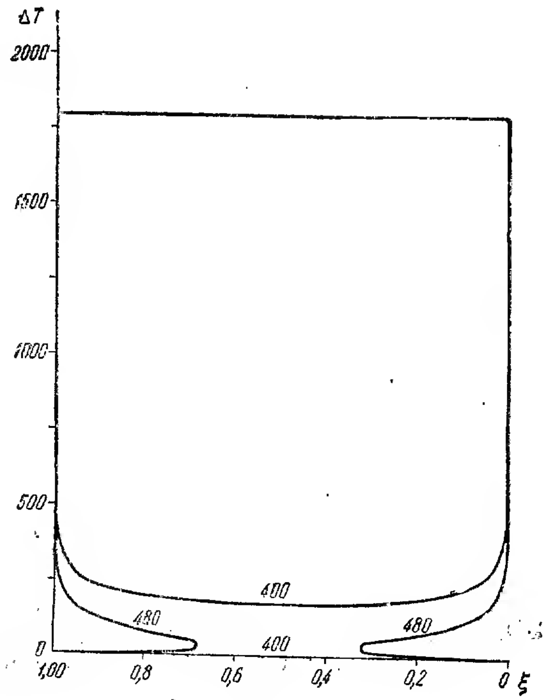

Fig. 2.

With increasing γ the value of ϑ_2 grows towards ϑ_3, and, if the conditions are suitable, will coincide with it. If the coal is burning, it will now cease to do so.

If at the outset only a slow process is possible—oxidation, and afterwards as the zone of reaction shifts, the curves z_1 and z_2 come to intersect at three points, then no burning will take place unless there is a layer of ash of adequate thickness.

If only stable burning is possible at the outset, and afterwards the curves z_1 and z_2 will intersect at three points, then in the presence of an ash layer of sufficient thickness a decrease in the temperature of the burning object will eventually bring the burning process to an end.

Using this graphical method one can also establish how the process is influenced by the conditions under which it proceeds.

7. More definite data on the variation of ϑ_1, ϑ_2 and ϑ_3 in a coal sphere, under certain conditions, as the zone of burning shifts, are given in Figs. 2 and 3, where $\Delta T = \vartheta_1 - T_0$, $\vartheta_2 - T_0$ and $\vartheta_3 - T_0$ are plotted against ξ. The plotting has been made on the assumption that α and α_d are infinitely great, $k_0 c_0$ is put at $5.74 \cdot 10^4$ (for the air), $E = 35\ 500$, and λ and D are taken to be equal to the respective values for the air.

The curve in Fig. 2 is for a sphere of radius $r_0 = 1$ cm, burning in the air whose temperature is 400 and 480 °C. The results obtained for a sphere of unit radius are shown in Fig. 3. The temperature of the air in this case is put

at 480°C, and the concentration of oxygen in the gas medium at 21, 10.5 and 5.25 per cent.

8. It has been shown above that on self-inflammation of the coal the curves z_1 and z_2 touch at the point $\vartheta_2 = \vartheta_1$. On the basis of this statement one

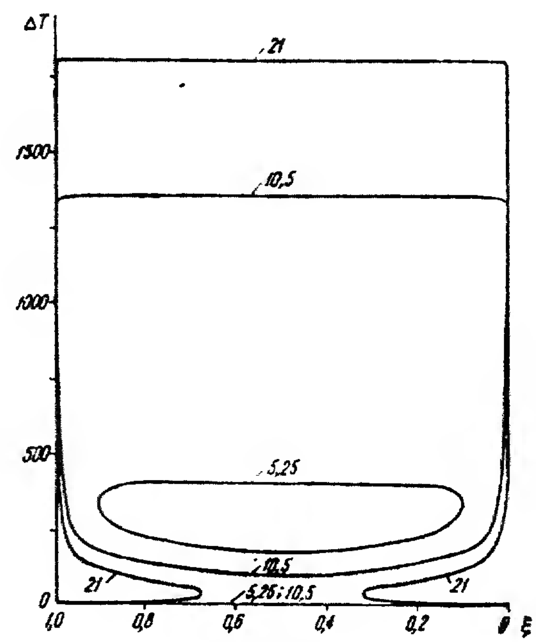

Fig. 3.

may easily show, following the method applied by Semenov ([3]), that the self-inflammation temperature should satisfy the approximate relation

$$qk_0c_0e^{-E/RT_i} = \alpha_0 \frac{R}{E} T_i^2$$

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PHYSICAL CHEMISTRY

AN ELECTRON MICROSCOPIC STUDY OF THE AGEING OF SMOKE DEPOSITS

By S. Z. ROGINSKY, Corresponding Member of the Academy,
A. B. SHEKHTER and S. V. SAKHAROVA

The possibility of directly observing the location and statistical distribution of the dimensions of submicroscopic particles in the electron microscope has made it possible in principle to observe the variety of changes in structure that are classed under the conventional terms of «ageing» and «recrystallization». As an object of investigation we selected the smoke deposits described elsewhere (1).

From the viewpoint of the problem stated above these smoke deposits possess two essential advantages: 1) they are incompact to such an extent as to show predominance of isolated particles, that are in no contact with other particles but at a few separate points; 2) because of the absence of a supporting film these preparations can be subjected to considerable heating.

The main observations were carried out on smoke deposits of gold and silver. In performing the experiments we availed ourselves of the possibility by repeatedly placing the specimen holder into the apparatus to return to the same field of vision, properly chosen and containing the characteristic structural formations.

The following procedure was adopted: first, we took photographs of the fresh deposit, then the holder with the mounted preparation was taken out of the apparatus and held at a definite temperature for a certain period. After that the holder was again placed inside the apparatus and more photographs were taken.

Not in a single case did we succeed to detect any change in the deposit upon keeping it exposed at room temperature. In several cases the preparations were kept in the mounted state for more than a month. When the temperature was raised, each preparation was found to possess a region of its own, in which the deposit began to undergo an appreciable change.

The changes observed in this case were of a varied nature. In the case of a smoke deposit of gold (Figs. 1 and 2), it could be seen that during the early stages of ageing there was a differentiation of particles according to dimensions: the number of biggest and smallest particles increased, and the distribution according to dimensions expanded, the middle part undergoing a decrease. The initial spherical shape of the particles was retained. This phenomenon should be taken as a matter of course, being just another example of big particles devouring the small because of the difference in surface energy. This takes place at temperatures excluding the possibility of either evaporation or fusion.

The only possible mechanism accounting for the redistribution of material is the Volmer lateral diffusion, the intensity of which must be quite

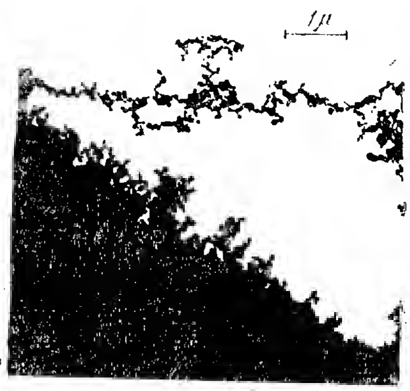

Fig. 1. Smoke deposit of gold, ×7300.

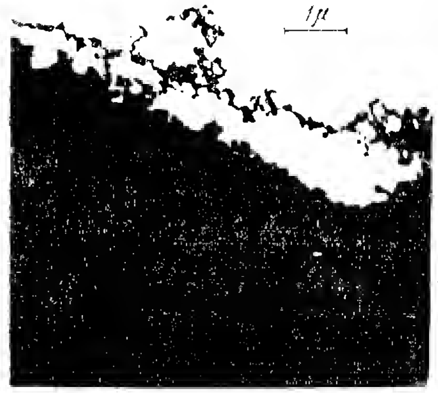

Fig. 2. Smoke deposit of gold after heating for $4^1/_2$ hours.

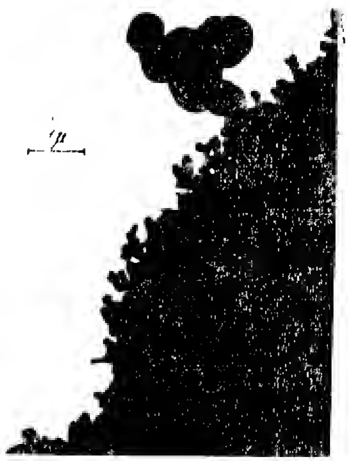

Fig. 3. Smoke deposit of gold after heating for $2^1/_2$ hours

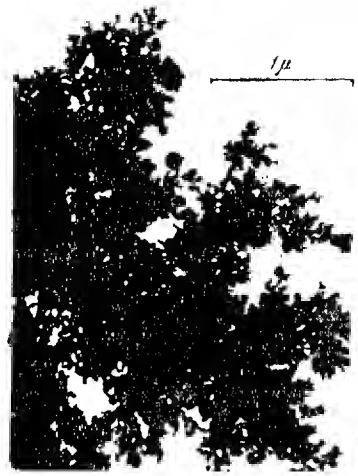

Fig. 4. Smoke deposit of silver. ×19 200.

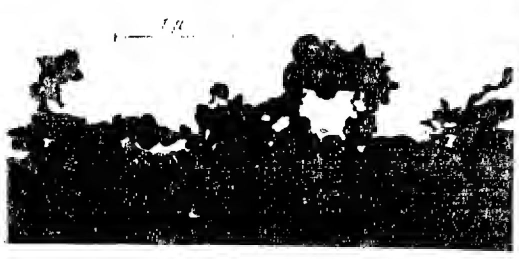

Fig. 5. Smoke deposit of silver after heating for 20 minutes.

considerable. Inasmuch as the initial structure shown in Fig. 1 represents a stretched chain, such a change in dispersity is inevitably accompanied by a longitudinal strain. The result must be either a settling of the whole chain

which becomes shorter (as was actually the case, and is shown in Fig. 2), or its break-up into separate links which are drawn together into more compact aggregates. Fig. 3 shows a case of more advanced ageing. In this case the greater part of the material has collected into large grains.

Heated smoke deposits of silver (Figs. 4 and 5) exhibit a more pronounced similarity with the crystal state. It was noted that silver ages easier than gold.

On the contrary, smoke deposits of zinc oxide and magnesium oxide withstand much higher temperatures without undergoing any change.

In these cases, apparently, Tammann's rule is observed in general, *i. e.* for the solid bodies of the same type the temperature, at which recrystallization begins, increases with the temperature of fusion, and is much higher for ionic lattices than for the metals.

Section of Catalysis and Topochemistry.
Institute of Physical Chemistry.
Academy of Sciences of the USSR.

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PHYSICAL CHEMISTRY

CATHODIC PROCESSES IN METALLIC CORROSION

By N. D. TOMASHOV

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An analysis of practical cases of corrosion leads to the conclusion that in most cases the cathodic process is the chief limiting (or controlling) factor in corrosion. Thus, a change in the rate of corrosion is usually associated with the kinetics of the cathodic process (except in cases of appreciably passivating corrosive systems). The importance of studying the kinetics of cathodic corrosion processes has already been emphasized by a number of authors [1-6].

The usual cathodic processes in practical cases of corrosion are either the assimilation of an electron as a result of the ionization of the oxygen dissolved in the electrolyte with the subsequent formation of OH′ ions (oxygen depolarization), or as a result of the discharge of the hydrogen ion with the subsequent evolution of the gaseous hydrogen (hydrogen depolarization).

In so far as the experimental investigation of cathodic processes usually involves the construction and analysis of polarization curves, it is expedient to give a graphic interpretation of the regularities observed in cathodic processes.

The figure shows such theoretical polarization curves, plotted by us on the basis of analytically established relations between the potential of the cathode and the change in the density of the polarizing current for different conditions of operations [6].

Curve *ABC* showing the overvoltage of oxygen ionization depicts the variation of the cathode potential with the current density, unless there is concentration polarization.

In that case the overvoltage of oxygen ionization (ϑ), *i. e.* the negative shift of the potential as compared to the equilibrium oxygen potential in the same solution, will be connected with the density of the polarizing current (I) by a logarithmic relation analogous to Tafel's formula for the overvoltage of hydrogen [6-8] *

$$\vartheta = a + b \lg I \tag{1}$$

where a is a constant depending upon the nature of the cathode and depolarizer and b is a constant determined by the mechanism of the depolarization process. The coefficient a in our case is taken equal to one volt, this being close to the experimental values of a which we obtained for a copper cathode. Coefficient b is given its theoretical value, equal—like the overvoltage of hydrogen—to 0.117 (for 20°C) [6].

Curve *ADBN* showing concentration polarization, *i. e.* the curve depicting the change in the cathode potential depending

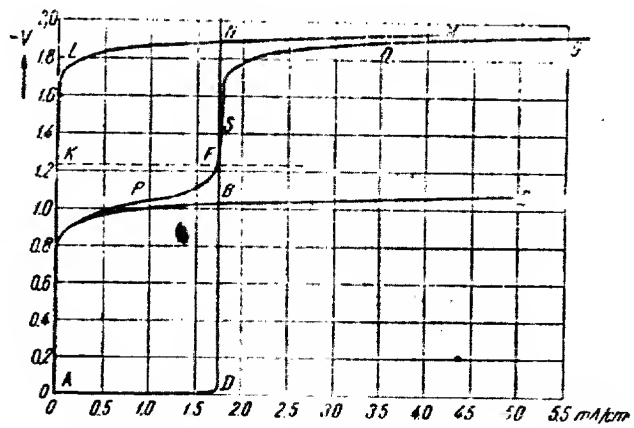
* With the exception of very small current densities (when the cathode potential shifts 30—50 mV from equilibrium), in which case we shall have a linear dependence [7, 8].

only upon concentration polarization in the total absence of the overvoltage of oxygen ionization, is determined by formula

$$\Delta\varphi = \frac{RT}{nF} \ln \left(1 - \frac{I}{I_d}\right) \tag{2}$$

where $\Delta\varphi$ is the departure of the potential from concentration polarization (the decrease of the oxygen concentration at the cathode due to the limited rate of its transportation). Here the term RT/nF is analogous to the similar term in the Nernst formula for calculating potentials; $n = 4$ is the number of electrons assimilated by one molecule of oxygen; I is the density of the cathode current when it becomes steady; and I_d is the limiting current, *i. e.* the current density under the maximum rate of oxygen diffusion possible in this case.

Like the curve showing the overvoltage of oxygen ionization, the concentration polarization curve takes its origin at the point of the oxygen's equili-



Theoretical curves of cathodic polarization.

brium potential, but has an opposite curvature. In distinction to the first curve, the growth of the current density in this case cannot exceed a certain limiting value, namely the value of the maximum diffusion current I_d. The value of I_d is determined by the conditions of the experiment, and to plot this curve I_d has been taken in accordance with its values obtained in experiments ([4-6]), *viz.* 1.75 mA/cm².

The oxygen polarization curve *APFSN* was obtained under such conditions of the cathode's operation, under which the overvoltage of oxygen ionization was accompanied by concentration polarization (the rate of oxygen transportation was limited). According to our analysis, in this case the dependence of the potential's negative shift ϑ_d upon the density of the polarizing current I will be determined by the following expression:

$$\vartheta_d = a + b \lg I - b \lg \left(1 - \frac{I}{I_d}\right) \tag{3}$$

where a and b are the above-mentioned constants, and I_d is the limiting diffusion current.

For small polarization currents (appreciably smaller than the limiting diffusion current) this curve will be near to the overvoltage curve for oxygen ionization. For polarization currents approaching the value of the limiting diffusion current, the curve of oxygen polarization will be close to the curve of concentration polarization.

An increase in the negative potential due to concentration polarization during cathodic polarization cannot continue indefinitely. As soon as the

Characteristic Points and Sections of Cathodic Polarization Curve in Metallic Corrosion

Designation of point or section	Characteristic features of given point or section	Location of points on cathodic polarization curve
P	1. The maximum rate of the reaction of cathodic depolarization is equal to the limiting diffusion rate of the depolarizer to the cathode 2. The concentration of the depolarizer on the surface of the cathode is equal to one half of its concentration in the midst of the solution 3. The resistance to the cathodic reaction is equal to the resistance to the process of oxygen diffusion, *i. e.* the cathodic process is controlled by the rate of the diffusion of the depolarizer instead of by the rate of the reaction	The current density is equal to one half of the limiting current of diffusion. The point potential is equal to the potential of the curve of the overvoltage of oxygen ionization for a current density equal to the limiting diffusion current
F	The process of hydrogen ion discharge begins (the beginning of hydrogen depolarization)	At an equilibrium potential of the hydrogen electrode in the given solution
S	1. The limiting diffusion current, *i. e.* the current determined by the maximum possible rate of diffusion of the depolarizer under these conditions 2. The concentration of the depolarizer at the surface of the cathode is equal to zero	At a current density at which the polarization curve becomes vertical, or, approximately, at the point of the second inflection of the cathodic polarization curve
Q	The rate of oxygen depolarization is equal to the rate of hydrogen depolarization	At the potential at which the curves of oxygen polarization and hydrogen polarization intersect. At a current density approximately double that of the limiting diffusion current
A—P	Section in which cathodic process is chiefly controlled by the rate of the cathodic reaction of oxygen ionization	—
A—F	Section in which cathodic process is completely controlled by oxygen depolarization	—
A—Q	Section in which the cathodic process is chiefly controlled by oxygen depolarization	—
P—Q	Section in which the cathodic process is chiefly controlled by the diffusion of oxygen to the cathode	—
Q—G	Section in which the cathodic process is chiefly controlled by the evolution of hydrogen (overvoltage of hydrogen)	—

potential of any new process is reached (in practice this is usually the discharge of hydrogen ions), the further dependence of the cathode potential upon the density of the polarizing current will be chiefly determined by this new process.

If in accordance with the well-known logarithmic relation for the hydrogen overvoltage, we represent by curve *KLNM* (see figure) the variaton of the electrode potential with the current density for the process of hydrogen evolution (h y d r o g e n p o l a r i z a t i o n c u r v e) *, *APFSQG* will be the general curve, which for short may be called the c u r v e o f o x y g e n - h y d r o g e n p o l a r i z a t i o n. This curve may be plotted by a simple summation of curves *APFSN* and *KLNM* along the x-axis.

The numerous experimental curves of cathodic polarization obtained by the author for various cathode materials are in good agreement (making allowance for a few well founded departures observed) with the calculated curve of cathodic polarization *APFSQG* ([6],[9]).

Our analysis of the cathodic curve of oxygen-hydrogen polarization ([6]) permitted us to define a number of characteristic points and sections of this curve (see table).

Such an examination of polarization curves is of considerable practical interest.

Indeed, if we know the potential of the cathode in the process of corrosion (for small ohmic resistances it is equal to the potential of the corroding metal), we may—on the basis of the curve of cathodic polarization for the given corrosion process—fully characterize the cathodic process: determine the relation between hydrogen and oxygen depolarization, the relative value of overvoltage of oxygen ionization and the limiting diffusion current. This is achieved by simple examination of the location of the point representing the cathodic potential during corrosion on the cathodic polarization curve, according to data given in the table. In the case where the corrosion process is controlled chiefly by the cathodic process, such a characteristic of the cathodic process is, generally speaking, a characteristic of the corrosion process as a whole.

The possibilities offered by the use of polarization curves and their construction from experimental data have been discussed elsewhere in greater detail ([6],[9]).

Laboratory of Corrosion of Alloys.
Institute of Physical Chemistry.
Academy of Sciences of the USSR.

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* Concentration polarization is not of great importance in the process of hydrogen evolution, as the hydrogen formed on the surface of the cathode -in case where it is not immediately removed—may be evolved in the form of gas bubbles without any difficulty. Thus, the curve of polarization occurring at the expense of the discharge of hydrogen ions (the curve of the overvoltage of hydrogen evolution) may in the first approximation be identified with the curve of hydrogen polarization.

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GEOLOGY

CHANGES IN THE MODE OF SEDIMENTATION IN THE CASPIAN SEA WITHIN HISTORICAL TIME

By S. W. BRUJEWICZ

(Communicated by P. P. Shirshov, Member of the Academy, 24. IX. 1945)

While studying the chemical composition of bottom sediments of the Caspian Sea, the author took and examined in the course of 1935—1940 core-samples at 25 stations. The variations along the vertical of the bottom deposits studied give a picture of the general changes in the physical geographical conditions of the sea.

Bringing out a number of regional characters, the vertical run of variation in the components of the Caspian sediments points at the same time to the following alterations, which are of rather general nature. At several stations of the North Caspian, *viz.* at those of the Tiub-Karagan gulf Γx 81, Γx 83, Γx 85, Γx 92, at the Lbishchenski shoaly slope (st. 19) is recorded a reduction in the content of carbonates in the upper horizons, which is especially conspicuous in the Tiub-Karagan gulf. This should be taken to mean that the supply of aeolian material from the land has been intensified here during the recent time. The rapidly accumulated fluviogenic sediments of the western part of the Northern, and particularly of the Middle Caspian Sea, are highly homogeneous along the vertical; they do not point to any essential changes in the conditions of sediment accumulation which would have occurred within the recent centuries.

In the South Caspian, within the area of the sea basin, of the eastern slope and the eastern shelf, there was observed an increase in the content of calcium carbonate and a decrease in that of Fe, Mn and P downwards.

In the region of the sea-bed, in the northern basin of the South Caspian (station 26) takes place a well-pronounced transition from the upper layer, 40 cm thick, with a $CaCO_3$ content of 17—21 per cent only, to the fiftieth centimetre and underlying layers, whose $CaCO_3$ attains 45.6 per cent.

In the southern basin of the South Caspian (station 50) the sediments are poor in calcium carbonate, homogeneous, and no underlying sediments high in $CaCO_3$ could be found there within a thickness of 110 cm of the core.

In the region of the eastern slope (station 28 and Γx 48) the content of $CaCO_3$ must likewise show an increase down the vertical, though not so clearly pronounced. The thickness of the upper layer is 40 cm.

The same phenomenon is observed in the eastern shelf, where it is less sharply pronounced, however.

Special interest belongs to the sharp increase in the carbonate content in the under layers in the region of the northern basin of the South Caspian (station 26). The theory of «landslips from the western slope» should be flatly discarded for the following reason. At the station «Piksha» 21 (section Kurin-

Content of Carbonates and of Fe, Mn and P in an HCl Extract from Mud Cores of the Caspian Sea

Horizon of bottom deposit, in cm from surface	CO_2 recalculated to $CaCO_3$, in % to abs. dry matter	Insoluble in 10% HCl residue, in % to abs. dry matter	10% HCl extract in per cent					
			to absol. dry matter			to residue insoluble in HCl		
			Fe	Mn	P	Fe	Mn	P
1	2	3	4	5	6	7	8	9
North Caspian. Tiub-Karagan Gulf, 1.XI.1939. St. Гх 81: 6.5 m. corner of the gulf								
0–17	25.8	53.9	2.07	0.044	0.067	3.86	0.082	0.126
17–20	28.6	52.2	1.75	0.042	0.062	3.35	0.081	0.119
20–40	28.0	53.8	1.58	0.045	0.063	2.95	0.084	0.117
40–50	40.1	48.3	0.85	0.034	0.053	1.76	0.070	0.110
50–83	37.7	49.6	1.32	0.046	0.054	2.66	0.093	0.109
St. Гх 83; 7 m. north of the st. Гх 81								
0–7	33.1	47.5	1.41	0.033	0.052	2.95	0.069	0.110
7–15	33.8	50.0	1.43	0.036	0.043	2.86	0.072	0.086
15–30	50.2	41.7	0.30	0.024	0.026	0.72	0.058	0.062
50–60	55.4	38.5	0.51	0.028	0.042	1.32	0.073	0.109
80–92	50.9	41.8	0.54	0.033	0.041	1.29	0.079	0.098
St. Гх 85: 8.5 m								
0–5	32.3	52.7	1.05	0.039	0.030	2.00	0.074	0.057
5–10	34.4	51.2	1.38	0.041	0.030	2.69	0.080	0.057
10–20	52.4	38.8	0.58	0.030	0.031	1.50	0.077	0.080
50–67	58.4	36.9	0.39	0.022	0.031	1.06	0.060	0.084
North Caspian. open sea. Lbishchenski shoaly slope of the N. Caspian. St. 19: 5 m. 26.VI.1940								
0–5	31.6	40.7	1.55	0.039	0.041	3.40	0.083	0.087
5–10	46.6	40.2	0.81	0.031	0.029	2.01	0.077	0.072
10–12	44.0	43.6	0.51	0.030	0.028	1.18	0.069	0.066
Near Chasovaya banka. St. 44: 4.3 m. 2.VII.1940								
0–5	10.9	68.7	2.62	0.074	0.066	3.83	0.108	0.096
5–10	13.0	70.1	2.05	0.078	0.060	2.92	0.111	0.086
10–20	11.4	73.0	2.15	0.074	0.056	2.94	0.101	0.077
20–30	8.3	79.1	1.34	0.039	0.043	1.70	0.049	0.054
North the Agrakhan Gulf. St. 47: 8.3 m, 4.VII.1940								
0–5	11.8	67.3	2.65	0.072	0.055	3.93	0.107	0.082
5–10	10.5	69.9	2.47	0.100	0.055	3.55	0.144	0.079
50–64	9.4	72.4	2.29	0.077	0.053	3.17	0.106	0.073
Middle Caspian, western part, near Makhach-Kala. St. 1: 19 m. 9.V.1940								
0–5	12.6	68.6	2.82	0.065	0.058	4.10	0. 95	0.084
5–10	12.6	66.2	3.36	0.080	0.054	5.08	0.121	0.082
50–64	13.1	70.4	2.08	0.052	0.051	2.96	0.074	0.072
North-east of the Kaliazin spit. St. 130: 258 m. 28.IV.1940								
0–5	14.4	65.6	2.68	0.061	0.064	4.10	0.093	0.097
5–15	11.1	68.4	2.78	0.075	0.072	4.06	0.124	0.105
15–60	11.9	70.4	2.77	0.067	0.068	3.92	0.095	0.096
Eastern shelf, WNW of Gulf Synghyrli. over shell limestone. St. 13; 114 m, 1.V.1940								
0–5	57.6	25.6	0.60	0.020	0.037	2.34	0.078	0.144
5–15	43.8	47.7	0.73	0.025	0.031	1.53	0.054	0.065
15–29	31.6	57.6	1.66	0.050	0.053	2.89	0.087	0.092
South Caspian, western part of section Island Zhiloi—Cape Kuuli. St. 16; 100 m, 15.V.1940								
0–5	39.2	—	3.72	0.074	0.096	—	—	—
5–10	31.2	56.3	1.90	0.053	0.044	3.37	0.094	0.078
10–20	16.5	69.7	2.74	0.054	0.053	3.93	0.077	0.075
20–38	12.0	75.4	2.48	0.061	0.062	3.30	0.081	0.082

Horizon of bottom deposit, in cm from surface	CO_2 recalculated to $CaCO_3$, in % to abs. dry matter	Insoluble in 10% HCl residue, in % to abs. dry matter	10% HCl extract in per cent: to absol. dry matter			to residue insoluble in HCl		
			Fe	Mn	P	Fe	Mn	P
1	2	3	4	5	6	7	8	9
Same, western part. St. 17; 172 m, 14.V.1940								
0—5	21.3	65.6	3.92	0.029	0.109	5.95	0.044	0.166
5—15	16.3	71.2	3.14	0.031	0.066	4.40	0.044	0.093
15—35	18.1	70.7	2.22	0.035	0.066	3.15	0.049	0.093
Same, in the trough cutting the submarine Apsheronian ridge. St. 18; 200 m, 14.V.1940								
0—5	13.6	73.1	2.44	0.062	0.056	3.33	0.085	0.076
5—15	13.1	76.7	2.72	0.059	0.041	2.55	0.077	0.053
15—30	11.8	72.8	1.94	0.059	0.038	2.65	0.081	0.052
Northern basin of the South Caspian section Kurinski Kamen—Ogurchinski. St. 26; 960 m, 31.V.1940								
0—10	21.2	63.6	2.89	0.086	0.055	4.54	0.136	0.086
10—20	17.5	56.6	2.29	0.108	0.056	4.05	0.191	0.099
20—30	20.7	64.2	2.25	0.139	0.052	3.50	0.216	0.081
30—40	20.9	60.3	2.53	0.095	0.045	4.20	0.157	0.074
40—50	28.6	53.1	2.30	0.118	0.047	4.32	0.221	0.088
50—60	45.6	50.3	1.94	0.105	0.049	3.85	0.208	0.097
Average	—	—	—	—	—	4.07	0.188	0.086
Southern basin of the South Caspian. St. Гх 50; 900 m, 20.XII. 1936								
0—15	17.7	64.9	2.51	0.119	0.064	3.86	0.184	0.099
25—45	21.7	61.5	2.50	0.100	0.046	4.06	0.162	0.075
60—80	21.4	60.6	2.41	0.091	0.065	4.07	0.150	0.107
100—110	19.4	63.2	2.50	0.079	0.066	3.95	0.125	0.104
Average	—	—	—	—	—	3.99	0.155	0.096
Eastern slope, section Kurinski Kamen Island—Ogurchinski Island. St. 28; 460 m, 1.VI.1940								
0—5	49.8	37.9	1.53	0.086	0.056	4.05	0.227	0.148
5—10	51.8	35.0	1.15	0.089	0.057	3.28	0.254	0.162
10—20	54.4	34.3	1.14	0.075	0.049	3.32	0.218	0.143
20—30	49.8	35.4	1.28	0.051	0.042	3.61	0.144	0.119
30—40	53.8	34.1	0.96	0.058	0.036	2.80	0.170	0.107
40—50	67.3	30.7	1.04	0.054	0.041	3.38	0.176	0.143
50—60	59.1	27.5	1.09	0.053	0.039	3.95	0.192	0.142
60—70	59.7	28.7	0.97	0.044	0.033	3.37	0.153	0.115
Average	—	—	—	—	—	3.47	0.192	0.135
Same, SW of the Mud volcano shoal. St. Гх 48 bis; 580 m, 18.XII.1936								
0—20	45.5	40.2	1.72	0.079	0.046	4.28	0.196	0.114
60—80	48.9	37.5	1.48	0.052	0.050	3.95	0.138	0.133
80—90	55.8	31.5	1.30	0.046	0.037	4.12	0.146	0.117
Eastern shelf. St. Гх 47; 33 m, 17.XII.1936, west of Zelenyi Bugor								
0—20	71.8	17.7	0.68	0.020	0.027	3.85	0.113	0.152
20—40	73.3	17.6	0.72	0.020	0.027	4.08	0.114	0.153
40—60	76.1	14.6	0.61	0.019	0.022	4.17	0.130	0.151
60—80	77.4	14.3	0.62	0.019	0.020	4.34	0.133	0.140
80—97	78.5	14.4	0.55	0.018	0.025	3.82	0.125	0.174
Average	—	—	—	—	—	4.05	0.123	0.154
Same, section Kurinski Kamen Island—Ogurchinski Island. St. 29; 85 m, 2.VI.1940								
0—5	56.6	26.6	0.90	0.031	0.040	3.39	0.117	0.150
5—10	61.6	23.6	0.40	0.018	0.021	—	—	—
Krasnovodsk Gulf. St. K7; 9.5 m, 18.XI.1935								
0—10	43.5	35.65	0.97	0.019	0.055	2.72	0.053	0.154
10—40	44.9	36.96	0.87	0.019	0.047	2.35	0.052	0.128

ski I.-Ogurchinski I. referred to above, east of our station 26), at a depth of 860 m, T. I. Gorshkova observed similar phenomena, *viz.* a carbonate content of 19.4—17.4 per cent in the upper 40-cm layer, and of 43.2 per cent beginning with the 60th centimetre (besides these, no measurements have been made). For the «landslip» a rise by 100 m is excessive. According to data by G. G. Sarkissian (core samples up to 2.5 m) within the region of the basin of the Middle Caspian, at the deepest layers of the sections Gulf Peschany—Gulf Buynak, and especially Derbent—Sue there occur deposits showing a much higher content of carbonates and a coarser mechanical composition. The nature of sediments speaks against the theory of landslips in this case, too. We are thus led to conclude that the phenomenon of decrease of the carbonate content in the sediments formed during the recent epoch is peculiar to the Middle and South Caspian as a whole, and is not connected with landslips. In so far as under the conditions of sedimentation that prevail in the Caspian Sea the variation of carbonate content points to a variation in a given place of the intensity of precipitation of fluviogenic and aeolian talassogenic sediments, the phenomenon here described cannot be accounted for otherwise than in the following way: During the epoch preceding the recent one the zone of expansion of solid matter discharged by rivers has been pronouncedly extended from west to east. This refers both to the sea basin and the lower part of the eastern slope. The decrease in the carbonate content in the eastern shelf took place because of the prevalence of precipitation of aeolian sediments poor in carbonates and rich in Fe, Mn and P over the purely talassogenic deposits high in carbonates, which was due to the intensification of winds blowing from the east.

It seems most natural to explain both phenomena by a common cause, *viz.* by a general increase in the atmosphere circulation, which is supposed to have taken place during the last thousand years. Because of the increased pressure within the area of the Siberian winter anticyclone, the latter phenomenon is associated with an increase in the Caspian region of winter winds blowing from the east and carrying aeolian matter from Central Asia. On the other hand, any increase in the displacement of the upper water layer of the Caspian westward results in an increase in the eastward compensatory movement of the deep waters carrying particles in suspension.

The recent epoch of low carbonate content embraces a time interval of about 1000 years; the epoch of transition was a very short one, of no more than 200—300 years. The data available are insufficient to determine precisely how remote was the epoch of high carbonate content.

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GEOLOGY

AN ATTEMPT AT A GENETIC CLASSIFICATION OF FIRE CLAYS AND REFRACTORY CLAYS IN WEST SIBERIA

By V. P. KAZARINOV

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Fire clays and refractory clays are among the products of Meso-Cenozoic weathering crusts widely developed in West Siberia. In the Lower Cretaceous and Lower Palaeogene time processes of chemical weathering which produced the weathering crust went on over a vast territory. The chemical weathering of various stone and loose rocks over vast areas of a peneplained country would bring about the formation of decomposition «eluvium» of a considerable thickness, which represents a residual form of the weathering crust. During the decomposition of various rocks in the course of migration a large number of various elements were supplied in the form of true solutions and colloids. The less resistant sols were falling out, forming sediments chiefly in shallow-water lakes and bogs. To these water bodies were also supplied small particles in suspension, washed out of the weathering crust at some points, and sometimes also a coarser clastic material. Deposits of variegated clays—gelites—were formed; occasionally iron and aluminium ores, as well as refractory clays, were separated out. In a great majority of cases the gelites are directly overlying the decomposition eluvium.

In the later half of the Lower Cretaceous, at the period when the Upper Cimmerian phase of tectogenesis was complete, a thick weathering crust was formed in West Siberia. The gelites of this weathering crust are widespread in the Chulym-Yenissei depression. They rest here upon the decomposition eluvium formed through the kaolinization of loose rocks of the lower part of the Lower Cretaceous and Jurassic.

The formation of the Lower Cretaceous weathering crust was interrupted by the Austrian phase of tectogenesis. The peneplain fell into areas of depressions and elevations; from the latter products of the weathering crust were washed away. In the depressions Upper Cretaceous loose sediments were accumulated, among which a considerable part was played by quartz sands and refractory clays.

At the beginning of the Palaeogene, at the close of the Laramic phase of tectogenesis which renewed the erosion processes called forth by the preceding phase, the country reached again the level of a peneplain, on the surface of which a new Lower Palaeogene formation of the weathering crust was produced, forming its own horizon of gelites and its own decomposition eluvium. Within the areas of the peneplained country where exposed at the surface were pre-Mesozoic country rocks (Kuznetsk Alatau, Salair, *etc.*), there was formed a decomposition eluvium, unlike the one simultaneously formed over areas where loose rocks were exposed at the surface (Chulym-Yenissei, Nensk-

Chumysh and other depressions). The redeposited products of the Lower Cretaceous weathering crust at the epoch of the Lower Palaeogene weathering crust were subject to kaolinization again, which to a considerable measure improved the quality of the clays, at certain points separated out within the areno-argillaceous deposits of the Upper Cretaceous.

Upheavals associated with the Alpine cycle of tectogenesis which followed the Eocene interrupted the formation of the Lower Palaeogene weathering crust. Its products, as well as those of the Lower Cretaceous weathering crust locally preserved, were washed away from the raised areas and redeposited in the areas of depressions. Unlike the redeposited products of the weathering crust of Upper Cretaceous age they suffered no decomposition, owing to which they often carry non-kaolinized admixtures and occur among polymikt loose rocks.

The group of primary deposits of clays is subdivided into deposits of clays entering into the composition of the accumulation products of the weathering crust, and deposits of clays taking part in its residual products. Among deposits of decomposition eluvium, deposits of ortho-, para- and neoeluvium are distinguished ([1]). Orthoeluvium is a decomposition eluvium formed at the expense of magmatic rocks and of rocks approaching these in composition (granites, effusives, gneisses, *etc.*). The name of paraeluvium is given to a decomposition eluvium formed at the expense of lithified sedimentary rocks (shales, sandstones, *etc.*). Finally, neoeluvium has been formed by a decomposition of non-diagenized loose sediments (sands, clays, *etc.*).

Clays of the Gelite Horizon

Fire clays and refractory clays of the gelite horizon are widespread in the Chulym-Yenissei, Nensk-Chumysh and near-Salair depressions, within the south-western and north-western near-Salair area, in the Kolyvan-Tomsk folded zone, in the cis-Altai plateau, and on the northern slopes of the Kuznetsk Alatau. In the form of patches, irregular in shape and variously coloured, these clays are distinguishable among the common bright-coloured gelites. From the data obtained by studying 9 deposits, their chemical composition varies in the following range: silica, 52.1—76.2 per cent, on the average 60.2; alumina, 16.2—33.9, on the average 22.1; ferric oxide, 2.3—8.1, on the average 5.2 per cent. Loss on ignition, 4.7 to 10.2, on the average 7.2 per cent; refractoriness, from 1450 to 1720°C, on the average 1590°C. The clays form a semi-acid, more rarely basic, ferruginous, refractory, and fireproof raw material. They are suitable for the manufacture of fireproof and refractory articles, in which a rather high iron content is permissible, and for satisfying the needs of the ceramic industry.

Clays of Orthoeluvium

Clays of the orthoeluvium are known among the products of the weathering crust in the cis-Altai plateau, on the northern slopes of the Kuznetsk Alatau, within the area of development of granites of the Novosibirsk intrusion, in Salair, in the Yenissei range. With regard to the mode of occurrence the clay deposits of this type represent pockets of weathering among original rocks, into which the clays gradually pass to a depth and following the strike. The properties of the clays of the orthoeluvium vary greatly according to the composition of the original rocks. The best clays (kaolins) of this group were formed at the expense of granites and other rocks of feldspathic composition. The chemical composition of such clays, according to the data of the study of eight deposits, varies within the following range: silica, 45.0—66.0 per cent, on the average 51.2; alumina, 24.1—42.3 per cent, on the average 33.1. Loss on ignition varies from 7.1 to 12.0 per cent, on the average 10.2; refractoriness, from 1640 to 1730° C and higher, on the average 1700°C. (The high

SiO_2 content of certain varieties of clays is accounted for by the presence of quartz; *e. g.* in clays formed upon the kaolinization of granites.) The predominant clay mineral of this particular group of clays is kaolinite. As to their properties and application, these clays are analogous to the kaolins of primary Ukrainian deposits.

Clays of a quite different kind are formed upon the weathering of felsoporphyrites and quartz porphyries of the cis-Altai plateau. These are acid and semi-acid low refractory clays.

Clays of Paraeluvium

Clays of paraeluvium are rather widespread within the Kolyvan-Tomck folded zone, a number of deposits are known from the Kuznetsk Alatau, in Salair, the Kuznetsk basin and the cis-Altai plateau. The overwhelming majority of these clays have been formed through kaolinization of shales. The mode of occurrence of paraeluvium clays is similar to that of the preceding group. According to data of a study of 40 deposits, the chemical composition of these clays varies within the following range: silica, 51.0—79.5 per cent, on the average 68.3; alumina, 11.1—23.9 per cent, on the average 19.1. Loss on ignition varies from 2.3 to 10.1 per cent, on the average 5.5; refractoriness, from 1350 to 1620 °C, on the average 1530° C. The predominating clay mineral of paraeluvium clays is monothermite (?). The clays may be used as fillers in paper and soap manufacture, *etc.*, for the production of low-refracting semi-acid articles, may be partly used in porcelain and faience industry and in other branches of ceramic industry.

Clays of Neoeluvium

Clays of neoeluvium are developed within the Chulym-Yenissei, Nensk-Chumysh and near-Salair depressions, where they have been formed by a kaolinization of Jurassic and Cretaceous rocks. The properties of neoeluvium clays differ greatly and depend on the composition of the original rocks.

The chemical composition of clays formed by way of kaolinization of mainly Jurassic and Lower Cretaceous rocks varies within the following range (according to the data of a study of eight deposits): silica, 58.7—78.5 per cent, on the average 66.0; alumina, 16.9—27.1 per cent, on the average 18.7. Loss on ignition varies from 5.3 to 11.2 per cent, on the average 6.3; refractoriness, from 1500 to 1680° C, on the average 1550° C. Like the clays of the two preceding groups the neoeluvium clays described compose weathering pockets among non-weathered original loose rocks.

The neoeluvium clays formed by way of kaolinization of the redeposited products of the weathering crust have properties of a different kind. According to data of a study of 25 deposits studied the chemical composition of clays of this particular type varies within the following range: silica, 42.3—66.7 per cent, on the average 57.7; alumina, 19.2—38.6 per cent, on the average 28.3. Loss on ignition varies from 6.3 to 14.4 per cent, on the average 10.6; refractoriness from 1610 to 1750°C, on the average 1690°C. Clays of this type show variable properties: they occur in the form of beds and lenses of various size among Upper Cretaceous kaolinized quartz-clayey sediments. The largest fire-clay deposits in West Siberia belong to clays of this particular type.

The quality of clays of neoeluvium depends on the composition of the original decomposition eluvium to which they owe their origin. Numerous deposits found among Upper Cretaceous quartz-clayey sediments along the projections of crystalline, mainly feldspathic rocks of the Yenissei range, are made up by basic high-refractory white clays, of which the predominant mineral is kaolinite. Along the western border of the Chulym-Yenissei depression numerous deposits, occurring among Upper Cretaceous quartz-clayey sediments along projections of shales of the Kolyvan-Tomsk zone and of shales

and argillites of the Kuznetsk Permo-Carboniferous, are composed of low- and medium-refractory semi-acid clays, the prevalent minerals of which is monothermite. Clays of this particular type may be used in the kaolin refractory, porcelain and faience, and ceramic industries.

Redeposited Clays

Redeposited fire clays and refractory clays occur among Tertiary and Quaternary deposits of West Siberia, chiefly within areas of depressions. In the form of beds and lenses these clays occur among loose kaolinized sediments. Their quality is highly variable and depends on the composition of the original rocks of the weathering crust, the products of which they are. The clays of this particular group have suffered no weathering subsequent to their deposition, as it has been the case with the Upper Cretaceous clays of neoeluvium; they have therefore not been freed from detrimental impurities (iron, carbonates, *etc.*); their grade is much lower than that of the Upper Cretaceous clays of neoeluvium. The chemical composition of redeposited clays, according to data of a study of 10 deposits, varies within the following range: silica, 51.7—79.5 per cent, on the average 70.8; alumina, 11.1—32.2 per cent, on the average 18.1. Loss on ignition varies from 3.0 to 10.7 per cent, on the average 8.4; refractoriness, from 1400 to 1710°C, on the average 1510°C. Taking part in the composition of the redeposited clays are clays of all the classes.

In addition to the above-listed principal genetic groups, in West Siberia are known other secondary groups of fire clays and refractory clays, not mentioned here, which also take part in the composition of products of the weathering crust.

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GEOLOGY

TYPES OF NICKEL DEPOSITS OF THE REZHEV REGION (MIDDLE URALS)

By M. A. KARASIK

(Communicated by V. A. Obruchev, Member of the Academy, 23. II. 1946)

The nickel deposits of the Rezhev region have been investigated later than those of other more important nickel-bearing regions of the Urals. Large-scale work, carried on within recent years, has revealed a great variety of types of mineralization.

In spite of its comparatively small nickel reserves, the Rezhev region is of special interest, nearly all types of hypergene nickel deposits known from the Urals being discovered there. Thus, it shows in a varying degree typical features peculiar to South-Uralian deposits of silicate nickel ores ([1],[2]), to the deposits of the Ufaley type ([3]), and to typical sedimentary deposits of complex iron ores of the Khalilovo region ([4]). Quite recently the author has discovered also a type of nickel mineralization different from those listed above, which will be the subject of further study.

A vast majority of the prospected deposits of nickel ores and of detached points where nickel mineralization is displayed,—more than 50 in number—are located within the Rezhev massif of ultrabasic rocks ([5]), in the west bordering on the rocks of a granitic intrusion occupying small areas. The nickel ore deposits are confined to the peripheral parts of the above-named massif made up chiefly of hartzburgite serpentines.

From their morphological peculiarities, geological mode of occurrence and partly the composition of the ores, all the deposits and showings of nickel mineralization fall into the following types:

I. Deposits of nickel ores confined to caverns (karst cavities) in limestones.

A. Located in zones of contact of limestones with serpentines.

B. Located outside the zones of contact of limestones with serpentines.

II. Deposits of the fracture (linear) type.

A. Confined to the contact of serpentines with sedimentary rocks.

B. Confined to the contact of serpentines with granites.

III. Nickeliferous deposits of the ancient weathering crust on serpentines outside the zones of contacts and caverns (karst cavities).

IV. Nickel mineralization in brown iron-ore deposits, genetically related to the ancient weathering crust on serpentines.

V. Nickel mineralization in sedimentary deposits of oölitic hydrargillite brown ironstone ores.

Between some of the types listed, belonging with a few exceptions (type V) to concentration deposits associated with the ancient weathering crust on serpentines, there exist gradations and some interrelations due to their common conditions of genesis. This is especially true of the deposits of types I A and II A, which are the most numerous and the most important from the

economic standpoint. Of the total number of about 20 deposits prospected, 11 belong to type I A and 4 to type II A.

Deposits of the karst type are confined to discontinuous caverns (karst cavities) in marmorized limestones, stretched mainly in a direction approaching the meridional one; deposits of this type form as it were detached chains consisting of three or four deposits.

Morphologically, the deposits of the fracture type (II A) differ sharply from the karst type in having a steep dip and in being stretched in one direction, the ratio of width to length being up to 1 : 15—20. For deposits of the karst type this ratio varies from 1 : 2 to 1 : 6. The deposits of both types are associated with zones of tectonic weakness, being usually confined to limbs of anticlinal folds.

In the structure of the deposits here discussed predominant are the infiltrationed and redeposited types of the ancient weathering crust (1). The most widespread types of nickel ores are clays and ochres after serpentines, clays after shales and nickel eluvial-diluvial areno-argillaceous deposits. The principal nickeliferous minerals in these ores are nontronite, halloysite, psilomelane-wad and nickel hydrosilicates. The latter occur in insignificant amounts. Rather widespread are nontronized and disintegrated serpentines, distinguished, however, by a rather low nickel content.

Type I B is represented by one of the largest deposits—the main deposit. This deposit is distinguished by its being rather far removed from the exposures of serpentines (over 300 m). An essential part in the geological structure of the deposit is played by a dyke of diabase porphyrite, which is adjoined by a cavern (karst cavity) in limestones.

Eluvial clays after porphyrites present here in an insignificant amount are one of the principal types of nickel ores and consist essentially of kaolinite, serpentine, talc, sericite, nontronite, hydrogoethite, goethite and cobalt-nickeliferous wad. According to data by I. I. Ginsburg, in the upper horizons there were observed considerable amounts of montmorillonite.

Of practical interest is a new type of nickel mineralization (IIB), discovered by the author in the southern part of the Rezhev massif of ultrabasic rocks, where the occurrence of nickel is associated with eluvial-diluvial deposits in the zone of contact of serpentines with granites and has been recorded for a distance of over 1 km. The chief nickeliferous mineral here is jefferesite which forms small pockets and coatings. The enrichment of jefferesite with nickel formed from biotite was taking place in the course of hypergenesis through the displacement of magnesium. The possibility of vermiculites high in nickel being formed in this way has been shown experimentally; it is connected chiefly with the poor ability of such minerals to retain such bases as MgO and FeO (6). In addition to jefferesite, the occurrence of nickel is associated also with nontronite and serpentine.

The serpentines adjacent to the contact, belonging to recrystallized varieties (4), have been in a considerable degree turned to talc and nontronitized. Detached areas of the weathering crust represented by nickeliferous nontronite clays are traceable here to a depth of 8—10 m.

Small patches of the ancient weathering crust on serpentines unrelated to zones of contacts are known at several points of the Rezhev and Ostanin massifs. These deposits are of considerable practical interest in the middle part of the Alapaevsk massif of ultrabasic rocks, where rather thick zones of a nickeliferous eluvium of serpentines have been discovered.

Without discussing here the other types of nickel mineralization, it should be noted that type IV differs but little from the nickel ore deposits of the karst type. In many cases iron ores poor in nickel in the lower horizons pass into nickel ores rich in iron, which has been pointed out also by other workers (7,8).

The chemical composition of the ores, even within individual deposit, varies greatly, which is connected with the mineralization being localized

in narrow zones of contacts and adjacent caverns (karst cavities), where diluvial-eluvial deposits of the most diverse rocks have been accumulated. Nickel ores rich in iron are prevalent, while magnesial nickel ores are less widespread. In deposits of certain types the behaviour of cobalt is characteristic, as may be seen from the table.

Ore types	Types of deposits	Co : Ni
Magnesial nickel ores	Karst Fracture	1 : 24—1 : 50 1 : 40—1 : 90
	Residual weathering crust	1 : 35—1 : 40
Ferruginous nickel ores	Karst	1 : 10—1 : 20
Nickel cobalt-bearing iron ores	Karst	1 : 6

The predominant part of cobalt in nickel ores is associated with psilomelane-wad. The Co : Ni ratio in earthy wads usually ranges from 1 : 3 to 1 : 6, the nickel content being higher than in other analogous deposits [9,10]. In nickel-bearing nontronites and serpentine cobalt is contained in small amounts. A small part of the cobalt is associated with hydrogoethite.

In conclusion it should be noted that in connexion with the new data on the occurrence of nickel in the Rezhev region, obtained by the author, attention should be given to the study of the nickel mineralization associated with zones of contacts of serpentines with granites of other nickeliferous regions of the Urals, too.

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HYDROGÉOLOGIE

SUR LE CHANGEMENT DE COMPOSITION DES EAUX SOUTERRAINES DU PERMIEN ET DU CARBONIFÈRE LORS DE LEUR MÉLANGE

Par A. M. KOUZNETZOV

(Présenté par V. A. Obruchev, de l'Académie, le 25. II. 1946)

Le mélange des eaux dans l'écorce terrestre présente un phénomène assez commun. Il est admis de déterminer graphiquement la compozition des eaux salines en relation linéaire des volumes des eaux qui s'entremélangent et de leurs composants. Mais ce procédé n'est pas toujours applicable pour les eaux du Permien (1) et du Carbonifère (2) des régions du Kama. La composition de ces eaux nous fait penser qu'à l'état de mélange des changements notables devraient avoir lieu en tant que ces eaux sont saturées avec $CaSO_4$ et $CaCO_3$ et qu'elles contiennent de quantités diverses de NaCl, $MgCl_2$ et $CaCl_2$. Nous verrons plus loin que ce fait est confirmé par l'expérience.

Nous avons constaté expérimentalement les changements en concentration des ions SO''_4 et HCO'_3 des mélanges des eaux suivantes:

1. L'eau hydrogène sulfuré-sulfate de la couche du Koungour. L'échantillon a été prélevé au débouche du forage, au point d'écoulement spontané. L'eau est saturée avec $CaSO_4$, elle contient 350 mg/l H_2S, de l'azote, de méthane, de gaz carbonique, la tension générale de dissolution étant de 4 atmosphères environ.

2. Les eaux salines H_2S—Cl′—Na˙ de la couche supérieure du Carbonifère moyen, à une profondeur de 710 m, saturées avec $CaSO_4$ et contenant de l'azote, de méthane et du gaz carbonique.

3. Les eaux salines Cl′—Ca˙˙ de la couche inférieure petrolifère du Carbonifère moyen à une profondeur de 1030 m; elles sont saturées avec $CaSO_4$ et contiennent de l'azote, d'origine organique principalement, et des carbures d'hydrogène, à tension de dissolution à peu près égale à 70 atmosphères. Les eaux 2 et 3 sont les eaux sous pression, leur niveau statique est établi à une distance de 60—80 m environ de la surface.

Ces eaux ont déjà été décrites (1,2) et leur composition saline est caractérisée par les données suivantes (en g/l):

	1	2	3
Densité	1.039	1.187	1.173
$CaCO_3$	0.43	0.29	0.02
$CaSO_4$	4.19	2.37	0.74
$MgSO_4$	3.18	—	—
$MgCl_2$	0.53	5.70	25.05
$CaCl_2$	—	15.30	52.99
NaCl	49.80	247.90	131.58

Vingt et une combinaisons des mélanges d'eaux naturelles à différences de volume de 20 pour cent ont été préparées et maintenues à une température

de 18—20° C pendant 20 jours dans des ballons bouchés; ces mélanges ont été examinés et agités tous les jours. Les concentrations en SO''_4 et HCO'_3 de ces solutions ont été déterminées au bout de ce terme.

Au bout de 20 heures après le début du procédé on a vu apparaître dans la solution aux parois et au fond des ballons de cristaux en aiguilles qui avec le temps augmentaient en nombre et en dimension. De 7 à 8 jours plus tard les parois et le fond des récipients contenant les eaux 1 et 3 étaient couverts de cristaux, tandis qu'il se formait peu de cristaux dans les autres mélanges. La formation des cristaux était achevée au bout de 10—15 jours. Comme on pouvait s'y attendre, les précipités cristallins étaient composés de $CaSO_4$ et $CaCO_3$, dont la quantité était déterminée d'après la diminution de concentration en SO''_4 et HCO'_3 en comparaison avec la concentration initiale.

Le changement de concentration en SO''_4 dans toutes les combinaisons binaires est illustré par le graphique, fig. 1, sur laquelle les lignes droites

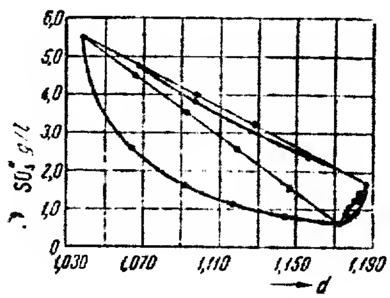

Fig. 1. Changement en concentration de l'ion SO''_4 lors du mélange des eaux 1—2—3.

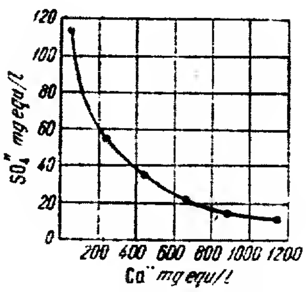

Fig. 2. Relation entre la concentration de Ca¨ et celle de SO''_4.

réunissent les points correspondant à la concentration initiale en SO''_4, les courbes—les points correspondant à la concentration restante en équilibre de cet ion dans les mélanges. La fig. 1 met en évidence que le dégagement du gypse est le plus intense dans les mélanges des eaux 1 et 3, le maximum de dégagement du sel solide—dans les mélanges à 70 pour cent de l'eau 1 et à 30 pour cent de l'eau 2. Dans ce mélange la diminution en SO''_4 est égale à 2.10 g/l, autrement dit, elle est voisine de 50 pour cent de la concentration initiale, ce qui fait, en calculant par rapport au gypse, 3.78 g, ou 1.65 cm³. En outre il se dégage de ce mélange 0.24 g $CaCO_3$. Dans les autres mélanges il se forme moins de gypse: les mélanges 1—2, de même que les mélanges 2—3 contiennent moins de 0.2 g/l; dans les mélanges ternaires sa quantité varie de 0.2 à 1.8 g/l.

La quantité de $CaCO_3$ de transformant en phase solide fait $^1/_2$—$^1/_4$ de sa teneur initiale dans les solutions des mélanges. Le maximum de dégagement a été constaté dans le mélange de l'eau 1 (80 pour cent) avec l'eau 2 (20 pour cent); il est égal à 0.32 g/l $CaCO_3$, ce qui fait 40 pour cent de sa teneur initiale dans la solution du mélange, avec un dégagement simultané de 0.08 g/l de gypse. Un fait caractéristique est à noter ici, notamment: il se dégage peu de gypse dans les mélanges 1—2 et relativement beaucoup de carbonate, tandis que les mélanges des eaux 1—3 dégagent beaucoup de gypse et considérablement moins de $CaCO_3$; en ce qui concernce les mélanges des eaux 2—3, elles ne dégagent en tout que 0.4 g de ces sels, avec prédominance de gypse dans le précipité (80 pour cent environ). Les mélanges ternaires des eaux 1—2—3 d'après le dégagement des sels solides occupent une position intermédiaire entre les compositions binaires. Il est donc clair que si le mélange des eaux sous pression du Carbonifère avec celles du Permien avait lieu, ce phénomène serait accompagné par une formation de $CaSO_4$ et $CaCO_3$

solides jusqu'à 4 g/l du mélange et par une incrustation de ces sels dans les fissures des roches.

La composition des eaux prouve que le dégagement de $CaSO_4$ et $CaCO_3$ des solutions est dû à la présence de $CaCl_2$, dont la concentration augmente au fur et à mesure que la solubilité du sulfate et du carbonate de calcium diminue, par conséquent la concentration de SO''_4, de même que celle de HCO'_2, dépend de la concentration de $Ca^{\cdot\cdot}$, ce qui est démontré sur la fig. 2 qui représente en toute évidence la concentration restante de $Ca^{\cdot\cdot}$ et SO''_4 dans les mélanges des eaux 1 et 3. Les sels NaCl et $MgCl_2$ présents n'exercent aucune action prononcée stimulatrice sur la solubilité de $CaSO_4$, ce qui était constaté pour ces sels en absence de $CaCl_2$ dans la solution ([3]).

La courbe démontre de même que les eaux naturelles peuvent être désulfatées aussi par des facteurs physico-chimiques, notamment, la diminution de la concentration de gypse dans la solution à mesure que celle-ci devient plus riche en chlorure de calcium. Ceci est de même lié au fait que les eaux des régions du Kama, fortement minéralisées, qui ont été étudiées par nous, se répartissent sur le graphique ci-dessus démontrant aussi que $[SO''_4]$ est en dépendance de $[Ca^{\cdot\cdot}]$ et que les eaux deviennent moins riches en sulfates à mesure que $CaCl_2$ s'accumule dans la solution (lorsque la teneur en gypse dans les roches est considérable).

De cette façon nous pouvons admettre que le processus d'enrichissement des eaux de l'écorce en calcium en fonction de la profondeur de leur gisement est accompagné d'une désulfuration physico-chimique ou, plus exactement, par une diminution de la concentration du gypse, du sulfate, dans les solutions. Les résultats de l'expérience nous amènent à la conclusion que les eaux présentes dans les roches et contenant l'anhydrite et le gypse sont saturées avec les sels, de sorte que ces aux, étant mélangées avec les eaux $Cl'—Ca^{\cdot\cdot}$, dégagent infailliblement du gypse et du carbonate, dont la présence nous fournit le moyen d'interpréter le processus qui avait eu lieu.

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GENETICS

CYTOLOGY OF POLYPLOID HYBRIDS *FRAGARIA GRANDIFLORA* × *F. ELATIOR* AND THEIR FERTILITY

By N. J. FEDOROVA

(*Communicated by I. I. Schmalhausen, Member of the Academy, 30. I. 1946*)

In 1929 we obtained hybrids, by crossing *Fragaria grandiflora* ($n=28$) with *F. elatior* ($n=21$). One partly fertile F_1 plant was studied in more detail. It appeared that chromosome conjugation at meiosis was of indefinite type. At diakinesis and at metaphase I there occurred cells with 28 chromosomes among which there were 21 II + 7 I. Along with these there were found cells with 35 chromosomes with 14 II + 21 I. Besides, meiosis in these hybrids was often accompanied with the omission of reduction division and the formation of diploid gametes.

In connexion with this a considerable variation in chromosome distribution was observed in the 2nd division. As a consequence of the aberrations noted above the sex cells of the hybrid had from 14 to 49 chromosomes. One might theoretically expect in F_2 the appearance of plants possessing from 28 to 98 chromosomes ($2n$).

As a matter of fact, the chromosome numbers in F_2 formed the following series ($2n$): 42, 56, 63, 70, 77, 84, and 98.

The vigour of the F_2 hybrids increased to a certain limit. This limit was imposed by the numbers 63—70, the plants with these numbers being the tallest and the most vigorous ones. With chromosome numbers above 70 the plants became smaller and, finally, the 98-chromosome plants were dwarfs. On the other hand, the dimensions of the somatic cells showed a constant increase with the chromosome number. The tissues of the 98-chromosome plants were composed of a relatively small number of gigantic cells. The increase in the number of chromosomes was accompanied in the hybrids by delayed blooming and seed maturity.

Meiosis was studied in the F_2 hybrids in every group of plants differing in somatic chromosome number. In 1st metaphase in 42-chromosome plants there were observed 2—3 polyvalents, 10—12 bivalents and 10—14 univalents. In 63-chromosome plants in 1st metaphase there were found from 3 to 8 polyvalents, from 9 to 28 bivalents and from 7 to 23 univalents. In 70-chromosome plants there were found 7—8 polyvalents, 13—16 bivalents and 10—12 univalents. In 77-chromosome plants we have observed 20—22 bivalents, 33—37 univalents. In the 1st metaphase of the 84-chromosome plants there were observed 2—3 polyvalents, 23—30 bivalents and 21—28 univalents. Finally, in 98-chromosome plants in the first meiotic division we could observe 5—6 polyvalents, 30—33 bivalents and 25—32 univalent chromosomes.

Attention was attracted by the inverse relation between the degree of polyploidy of the hybrid and the proportion of conjugating chromosomes.

Thus, for example, in 63-chromosome hybrids, the proportion of non-conjugating chromosomes was 17.4 per cent. In 84-chromosome plants 27.3 per cent of chromosomes did not enter conjugation. Finally, in 98-chromosome plants, in 14-ploid hybrids, 30.6 per cent of the chromosomes failed to conjugate, in spite of the fact that in this latter case every chromosome possessed a partner inasmuch as the hybrid contained both the maternal and the paternal full diploid chromosome complements.

The cause of the reduced conjugation along with the accumulation of homologous chromosomes lies in the fact that the majority of chromosomes are only partly homologous to each other, which leads, on the one hand, to the formation of unstable conjugants, and, on the other hand, requires more complicate conditions to make conjugation possible.

The fertility of the F_2 hybrids *Fragaria grandiflora* × *F. elatior* varied from complete sterility to fully fertile plants. Some of the hybrids were distinguished by abundant fruit setting. It was apparent that the degree of fertility of the hybrids was connected with the qualitative composition of the chromosome complement of the hybrid rather than with the chromosome number. Thus, for example, within the limits 42—56—63—70 and 73 chromosome groups there were fonnd both sterile and fertile plants. A comparison of the degree of fertility of the hybrids with the peculiarity of meiosis revealed a straight correlation between the two. In meiosis of the fertile plants there was a preponderance of bivalents, *i. e.* paired conjugation. An increase in the univalent and polyvalent chromosomes leads to reduced fertility. Data presented in the table confirm these statements.

$2n$	Fertile			Partly fertile			Sterile		
	Polyvalents	Bivalents	Univalents	Polyvalents	Bivalents	Univalents	Polyvalents	Bivalents	Univalents
42							2	10—12	10—14
63		28	7	—		—	—	—	—
63		25—27	9—11	—		—	—	—	—
63				3—4	9—16	13—17	—	—	—
63							4	9—14	19—23
63						—	6—7	10—12	15—17
70				—			7—8	13—16	10—12
77					20—22	33—37	—	—	—
84					—	—	2—3	23—30	21—26
98			—		—	—	5—6	30—33	25—32

Of special interest is the group with 63 chromosomes. In the fertile plants of this group polyvalents are absent, bivalents are at maximum and there are a few univalents. On the other hand, in the group of sterile plants there are always found polyvalents and many univalents. The quantitative relation between the numbers of polyvalent and non-polyvalent chromosomes is of great importance.

The presence of 2—4 polyvalents in the 42-chromosome group of plants sharply disturbs meiosis and causes sterility. An analogous phenomenon was observed in the 63-chromosome group—the occurrence of 3—4 polyvalents brings about a sharp reduction in fertility, and with 6—7 polyvalents, the plants become completely sterile.

The presence of a great number of homologous chromosomes thus becomes one of the causes of the disturbed chromosome balance and of the reduced fertility in the hybrids studied.

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BOTANY

RELICS OF THE TERTIARY FLORA OF THE USSURI REGION

By I. V. GRUSHVITSKY

(Communicated by A. A. Richter, Member of the Academy, 16. II. 1946)

The North Ussuri region is one of the less explored parts of the Soviet Far East. It is but natural therefore that the expedition sent in 1937 to the basin of the Khor River (north-western part of the Ussuri region) brought home, in spite of its short period of work, a number of highly interesting botanical-geographical findings.

In the present note I shall dwell upon a single group of plants which are of very rare occurrence on the Pacific coast (Primorie); these plants were discovered in the Middle Sikhote-Alin region, as well as in the regions of the South-Ussuri and of Sakhalin. As asylum for them served narrow valleys of mountain rivulets, cutting the belt of dark coniferous woods at an altitude of 400—900 m above sea level. On the steep slopes of narrow ravines covered with virgin fir-tree forests, in the region of the middle affluents of the Khor River (Katen, Kafen and Chuken), where I was travelling together with A. I. Kurenzov, we discovered dense thickets of the following plants: ferns, *Athyrium austroussuriense* Fom., *A. pterorhachis* Christ., *Coniogramma fraxinea* Diels and *Osmunda cinnamomea* L., dwarfish evergreen shrub *Ilex rugosa* Schmidt, *Corydalis gigantea* Trautv., *Taxus cuspidata* S. et Z. The alpine shrub *Microbiota decussata* Kom. and a plant from the family of Crucifers, *Macropodium pterospermum* Schmidt, which was found by me in the continental part of the Far East, as well as the ferns *A. pterorhachis* and *Osmunda cinnamomea* listed above, are dwellers of the same region, though mostly passing beyond the belt of woods, and of some other habitats.

Most of the representatives of this group of rare relics of the Tertiary (*Athyrium pterorhachis*, *Coniogramma fraxinea*, *Lycopodium chinense* Chr., *Mecodium Wrightii* Copeland*, *Osmunda cinnamomea*, *Phyllitis japonica* Kom.*, *Taxus cuspidata*, and others)* are characterized by a peculiar shape of their area of distribution, which embraces as a ring the coast of the Sea of Japan (6). During the long time these plants have lived there (most of the authors refer them to the Miocene (1)) individual representatives of this group of Tertiary relics have become extinct in definite parts of their ring-shaped area of distribution: some in the northern, others in the southern, north-eastern, and so on. As a result, the three main regions of rare Tertiary relics

* Asterisks serve to denote plants which are of rare occurrence on the Pacific coast and have not been found in the basin of the Khor River, but are met in other districts of the province, along with rare Tertiary relics and under similar living conditions. In the course of further exploration these plants are likely to be discovered in the region of the basin of the Khor River.

referred to above, giving shelter to about the same species, differ from one another by two or three species only. Thus, missing in the region of Sakhalin are *Athyrium austroussuriense*, *Gonocormus minutus* v. d. Bosch (= *Trichomanes parvulum* Poir.) and *Microbiota decussata*; in the South-Ussuri region, *Ilex rugosa* and *Macropodium pterospermum* and, lastly, in the region of the Middle Sikhote-Alin (valley of the rivers Khor, Bikin, Anuy) are lacking *Gonocormis minutus* and *Mecodium Wrightii* Copeland (= *Hymenophyllum Wrightii* v.d. Bosch).

It is not impossible, of course, that these gaps will be filled up, but in a few cases only, for the blanks are mostly due to a reduction in the area of distribution of a given species rather than to the poor state of exploration of the corresponding areas.

Considered from the point of view of ecology and geography, the group of rare Tertiary relics should be referred to the purely oceanic element * of the Pacific coast, the area of distribution of these plants corresponding to the Japan islands, Sakhalin, partly the Kurile islands (southern group), while two species, *Athyrium pterorhachis* and *Osmunda cinnamomea*, are distributed even over the Kamchatka peninsula. From the west the area of distribution of the majority of rare Tertiary relics is bounded by the western mountain chains of Sikhote-Alin; besides, they must have survived there because of the influence of a number of protective agents (see below).

Two rather peculiar features can readily be noticed in the mode of distribution of rare Tertiary relics over the Ussuri region:

1. They all are confined to the western mountain chains of Sikhote-Alin, while they are entirely lacking in the eastern chains of the mountain range and on the coast of the Japan Sea and of the Gulf of Tartary. This should probably be accounted for by the fact that the geologic past of the Sikhote-Alin mountains was not the same for their different parts. The eastern ranges have been formed at a rather recent epoch, at the close of the Tertiary or early during the Quaternary, through an upwarp of the Nippon geosyncline. Considerable upheavals in some places and subsidences in others must have called forth displacements of the vertical vegetation zones (³), which could not do otherwise than affect the preservation of ancient relic elements. Unlike this, the western mountain chains of the Sikhote-Alin, which constitute the most ancient part of the range, suffered no considerable vertical dislocation since the beginning of the Tertiary period. Owing to this, they offered optimal conditions for the preservation of ancient floristic elements.

2. Within the Pacific coast rare Tertiary relics have attained the highest degree of development in the region of the Middle Sikhote-Alin, *i. e.* in the region of the basin of the Khor River. Both north and south of this region the representatives of this group have suffered extinction. Their number is found to decrease considerably as we approach the northern part of the Sikhote-Alin, where but a few species could be found, which adapted themselves to the recent conditions (*Osmunda cinnamomea*, *Taxus cuspidata*, *etc.*). The number of localities and the abundance in these of the relic plants listed above decrease rapidly as we proceed northwards.

Curiously enough, both the abundance of these plants and the number of places of their occurrence are found sharply to decrease in the opposite direction, so that such species as *Ilex rugosa* and *Macropodium pterospermum* are practically lacking in the southern part of the Maritime province (Primorie). A similar phenomenon has been described by Kurenzov (⁴) for the ancient relic element of the entomological fauna of the same region.

Among the intricate complex of the various agents responsible for this strange anomaly, of paramount importance is the interference of man. The woods of the South-Ussuri have been much more badly affected by the acti-

* «Euozeanische Arten», according to the terminology by Degelius and Troll (²).

vity of man than the region of the Sikhote-Alin mountains. Scanty relics of the Tertiary actually survived in such places only which have remained untouched by fire, felling, *etc.* (5). No less important is the influence of the climate. According to Vorobiov (6), the tiny fern *Mecodium Wrightii* has survived in the region of Suchan because of the snow cover which in the Middle Sikhote-Alin mountains is much thicker than in the southern part of the Pacific coast. Data accumulated by bio-climatologists (7) and botanists (8) who were working in the Far East, make us conclude that the Sikhote-Alin mountains protect the vegetation against the deleterious effect of the cold marine climate (cold currents, fogs, winds). At a small distance from the southern and northern ends of the Sikhote-Alin range, which abut upon the shoreline, vegetation is found to develop better and earlier than close to the sea. The protective rôle played by the mountain range in the life of Tertiary relics must have been especially important during those remote times (the Tertiary period) when the North Pole, being shifted in the northern part of the Pacific Ocean, transformed the seas which washed the coast of the recent Primorie into near-polar reservoirs.

Owing to this, rare relics of the Tertiary, which represent purely oceanic elements of the flora of the Pacific coast, failed to survive on the seashore, but did so in the inland, where they are harboured by the lofty mountain range, in such places (asylums) which, owing to substituting agents (temperature inversion (9)) have a microclimate corresponding to that of the littoral. In this point the purely oceanic element of the Primorie differs essentially from that of West Europe, whose asylums in Norway are (because of the warm current (2)) confined to the shoreline.

Strictly speaking, the rare relics of the Tertiary form no single, homogeneous group either with respect to their age, or origin. A thoroughgoing analysis of their areas of distribution and affinity is likely to reveal their considerable diversity, both in age and origin. They have, however, a good number of characters in common. These are their disrupted area of distribution, mono- or olygotypic nature, isolated position within the system, the presence of ancient morphological characters, the evergreen habit of them, the lack of any close phytocoenological connexion with recent plant associations, their occurrence in the same asylums with ancient relic elements of entomofauna (4, 10), bryoflora (11) and flora of lichens and, lastly, the findings of fossil remains of these plants and of their closest relatives in the Tertiary deposits of the Pacific coast. All this is evidence of the fact that the group here discussed represents an ancient relic element, dating as far back as to the Miocene at least.

Being a remnant of the ancient flora which might have thriven on the Pacific coast many million a year ago, the group of rare Tertiary relics shows actually no signs of reduction of its area of distribution, or of extinction due to natural conditions. Except for the activity of man (especially, cases of fires) there are scarcely any reason for the extinction of these plants. In their asylums, the rare relics of the Tertiary are remarkable for their vitality and exuberance; occasionally they prove capable of secondary ecological and geographic distribution. This points to the fact that the recent climate resembles the one that prevailed at the remote epoch when the group of rare Tertiary relics enjoyed their widest distribution.

Chaney's conclusions (12) as to the fossil Miocene flora of the Shantung province and the Tertiary floras of the littoral of the northern part of the Pacific Ocean make us believe that the subtropical element within the group of rare Tertiary relics (for example, *Coniogramma fraxinea*) is more ancient still, dating as far back as the Early Tertiary.

The M. N. Pokrovsky
State Pedagogical Institute.
Leningrad.

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PLANT PHYSIOLOGY

ON THE THEORY OF OBTAINING HAY RICH IN PROVITAMIN A

By S. J. ZAFREN

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According to a number of students [1, 2, 3], cut grass should be dried as far as possible out of the direct action of sun rays, in order to obtain a high content of provitamin A. When grass is dried in the shade, the resulting hay contains more carotene than in the case the grass is dried in sun rays, although drying proceeds quicker in the latter case. This circumstance furnished ground for the conclusion made by Zhuravlev and Martinson [2], Huge [1], Popandopulo [3] and others, *viz.* that the main agent which destroys carotene is sun radiation.

Data obtained by Mikhin [4] have led to a conclusion which seems at first sight to be of an opposite character. This investigator applied a slight squashing of the culms of grass in order to bring about quicker drying; he proved that 70 per cent of carotene could be preserved in such a way when the grass was dried in sun rays. However, the figures obtained by Mikhin show that when dried in the sun, squashed alfalfa reached a 14 per cent moisture content as soon as after six hours and lost 28 per cent of the original carotene content; when dried in the shade, it attained the same moisture content only after 52 hours, and lost 45 per cent of carotene. The same regularity was found in the experiments by Mikhin with alfalfa subjected to ordinary drying process. Alfalfa which was dried in the sun had after 52 hours 19 per cent of moisture and contained 28.7 per cent of the carotene originally contained in the fresh grass. In the shade alfalfa attained a 21 per cent moisture content only after 78 hours, but it contained towards this moment as much as 36.5 per cent of the original carotene.

All the experimental data thus seem to demonstrate that sun rays destroy the carotene contained in the organs of green plants subjected to drying for hay.

The present author pointed out as early as in 1941 [5] that such a conclusion is scarcely in accord with a number of firmly established facts. First, in normally developing plants, a maximum carotene content is observed in such organs as are the best illuminated. It would suffice to note that the outer leaves of cabbage, of chicory and other plants contain more carotene than the inner ones; that etiolated plants contain scarcely any carotene if at all, the latter being formed only after the plants are exposed to light, *etc.* Secondly, it follows from experiments by Kirsanova [6] that the carotene contained in vegetable sap is highly resistant to ultra-violet radiation. Lubimenko [7] has pointed out that the pigments of chloroplasts, inclusive of carotene, do not begin to be destroyed under the influence of sun radiation until their connexion with the stroma of the plastid is disturbed. In fact, it is unquestion-

able that dry hay in which there occurred coagulation of the colloidal system is quickly bleached by sun rays; as to the possibility of photochemical destruction of carotene in cut grass at the initial stages of its dehydration, such a possibility seemed to be very doubtful in the light of the circumstances cited above.

On the other hand, data by Zechmeister ([8]), Godnev ([9]), O. Richter ([10]) as to the genetic affinity between carotinoids and chlorophyll, as well as experimental data and theoretical considerations by Sapozhnikov ([12]), as to the oxidation-reduction transformations of the system carotene—xanthopyll gave grounds to a suggestion that such a combination of surroundings was possible where the shifting of oxidation-reduction processes towards reduction may lead to an increase in carotene even after the plant has been cut off. We have already reported ([5], [11]) that carotene content could be increased in green plants subjected to silage. We have attempted to explain this phenomenon by the inactivation of oxidaze under the influence of low pH value and by the reduction of carotene from other pigments of the chloroplast.

In the light of the work by Sapozhnikov one could expect that carotene would accumulate in plants kept in the dark. Data by Rubin *et alii* ([13]), as well as by Ssysakian and Kobiakova ([14]) led to the conclusion that the intensity of oxidation-reduction processes in the plant varies in the course of a 24-hour day along with illumination. The oxidating activity of the leaves prevails at noon time, while the reducing activity prevails at later hours.

Our determinations have shown that the curve of the variation of carotene content in the leaves during 24 hours is parallel to the relation of oxidation to reduction capacity, as shown by Rubin *et alii*. The corresponding data are presented in Table 1.

Table 1

Variation in Carotene Content and in Oxidation-Reduction Activity of Leaves (carotene measured in mg% in dry matter. Oxidation-reduction activity expressed in ml of 2,6-dichlorphenol-indophenol solution per 10 g of leaves)

	Time of measurement				
	6 a. m.—7.30	11.30 a. m.—12	6 p. m.—7.30	11.30 p. m.—12	7 a. m.
Carotene	41.8	40.0	47.2	51.6	45.0
Reduction capacity	9.2	8.5	11.0	13.0	—
Ratio of oxidation capacity to reduction capacity	3.8	7.0	6.8	4.0	-

Rubin *et alii* have pointed out that the oxidation-reduction capacity of the plant cell appears to be highly labile with respect to environmental factors, and, in particular, to illumination conditions. If under changed conditions of alternation of light and darkness hydrolytic processes retain for some time their normal sequence typical of preceding developmental conditions, oxidation-reduction activity is soon disturbed in a way corresponding to the new conditions.

In order to check the possibility of shifting the equilibrium of the pigment system towards the accumulation of the carotene by placing the plants in the dark, experiments were arranged with plants growing on their own roots, and such plants as were previously severed. Under field conditions red clover plants were covered with boxes of black paper. After 4 hours average samples of leaves were taken from these plants; simultaneously samples were taken from plants grown in full illumination. The results of the respective analyses are given in Table 2.

Table 2

Carotene Content in Leaves of Red Clover Kept for 4 Hours in the Light or in the Dark

	Experiment 13.VII.1945		Experiment 17.VII.1945	
	Dark	Light	Dark	Light
Moisture content, %	76.8	72.0	76.1	71.0
Carotene, mg % in the dry matter	55.6	54.2	46.6	42.0

As seen from Table 2, scarcely any change in carotene content in the leaves was produced by keeping normally developing plants in the dark for 4 hours; one could only note a slight increase in carotene content.

A different picture was brought to light when severed plants were kept in the dark (Table 3). In this case three average samples of plants were taken. The leaves of the first sample were analysed immediately. The two other samples were kept for four hours, one of them under a glass bell and another under a similar bell which was covered with black paper. The leaves were then analysed.

It may be seen from the table that in all the three experiments the leaves kept under dark bells contained much more carotene than the original material. Evidently, this is the reason why drying in the dark is superior to that practised under sun rays. From the data obtained one may assume that the higher carotene content observed in hay prepared in the dark should be explained by fermentative formation of carotene in the dark, and not by its photochemical destruction. The presence or absence of light does merely determine the direction of the oxidation-reduction enzymic process. In this sense sun light should be regarded as an adverse agent in the process of preparation of hay rich in vitamin A. An additional proof of the correctness of this statement is furnished by the facts discovered by Hauge and Mikhin [1,9], *viz.* that after inactivating the enzymic system of the plant direct sun rays do not practically destroy carotene; as already noted, these considerations do not apply to the dry hay in which photochemical destruction of carotene takes place.

Table 3

Carotene Content in Leaves of Red Clover Cut off and Kept for 4 Hours in the Dark or in the Light

	Experiment 5.VII.1945			Experiment 23.VII.1945			Experiment 14.VIII.1945		
	Original leaves	After 4 hrs light	After 4 hrs dark	Original leaves	After 4 hrs light	After 4 hrs dark	Original leaves	After 4 hrs light	After 4 hrs dark
Moisture content, %	73.1	64.3	70.5	72.6	66.5	72.4	75.4	—	71.7
Carotene, mg % in the dry matter	45.7	49.5	57.2	44.4	44.8	50.0	46.3	—	66.9

The results communicated above give not only a consistent theoretical interpretation of the relative importance of the light factor and of enzymes in the process of the preparation of hay rich in carotene; they also open wide prospects for working out new methods for its preparation.

The W. R. Williams
All-Union Institute for
Fodder Research.

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PLANT PHYSIOLOGY

ON THE MOISTURE CONTENT, MOISTURE-HOLDING CAPACITY AND HYDROPHILY OF DRY MATTER OF THE LEAF SERIES IN WHEAT

By D. M. NOVOGRUDSKY

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As stated in an earlier note by the present author (1) the moisture gradient in the leaf series in annual grasses varies according to Krenke's law of age variation, passing from increase to decrease. The most probable explanation of the ontogenetic inversion of the moisture content gradient lies in the senescence of the leaf series. Starting from the concept which was previously worked out in detail by Ružička (2), *viz.* that processes of senescence are based upon an irreversible decrease in the hydrophily of the cell colloids, one might expect that not only moisture content, but other characteristics of water regime connected with the hydratation capacity of the cell colloids must likewise change in the course of ontogeny according to the same law, and be characterized by an age-curve with an ascending and a descending arm.

Observations went to confirm this conclusion. They were made on two varieties of soft wheat, *Lutescens* 062 and *Milturum* 0321, grown for comparative variety tests. Samples were taken for analysis by developmental stages, early in the morning after sunrise. In the leaf blades belonging to every leaf storey there were determined moisture content, moisture-holding capacity and hydrophily of the dry matter. Moisture content was found by desiccation to constant weight at 85—90°. Deviation in parallel determinations did not exceed 0.5 per cent (to dry weight). The moisture-holding capacity of the leaves was found by placing the plants for 12 hours by their roots and basal parts of shoots into water and by covering them with bells, after which moisture content was determined in the leaves of each storey. Deviations in parallel determinations were about 0.5 per cent.

For determining the hydrophily of the dry matter of the leaf blades the latter were desiccated in a thermostat at 32°. Smirnov (3) used for the same purpose desiccation *in vacuo* with phosphoric anhydride. Any mode of desiccation affects more or less profoundly the hydratation properties of the cell colloids, and it is far from being clear what are the conditions under which these changes are the greatest.

The desiccated material was ground in an agate mortar and sifted through a sieve (meshes 0.25 mm). Since keeping over pure water led to the development of moulds, the glasses with weighed portions of the dry matter of leaves were placed into closed desiccators containing at their bottoms a saturated solution of ammonia nitrate (the relative humidity of the air being about 52 per cent), and the amount of water vapour absorbed was determined after maximum saturation was attained. Using such a method the deviations

in parallel determinations attained in some cases 1 per cent. With small absolute values of the hydrophily index such a discrepancy could not be considered insignificant. The values of the hydrophily index of the dry matter are averages from two parallel determinations. It is self-evident that these indices are relative and can only indicate the direction in which the character in question had changed, its absolute value remaining unknown.

The results are summarized in the table. The moisture content and water-holding capacity are expressed in per cent to dry matter; the hydrophily, in per cent of water vapour adsorbed by the dry matter of the leaves above saturated solution of ammonium nitrate at room temperature (18—20°).

Moisture Content (*a*), Water-holding Capacity (*b*) and Hydrophily (*c*) of the Leaf Blades in Leaf Series of Wheat

Lutescens 062

Leaf storey	Tillering (29.V)			Culming (9.VI)			Blooming (1.VII)		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
1	284	327	7.0	—	—	—	—	—	—
2	320	381	8.3	—	—	—	—	—	—
3	487	650	9.5	304	326	6.9	—	—	—
4	—	—	—	334	378	8.5	—	—	—
5	—	—	—	334	359	7.8	249	282	—
6	—	—	—	300	354	7.5	210	260	7.4
7	—	—	—	257	292	7.2	178	208	7.0
8	—	—	—	251	273	7.0	141	179	6.8

Milturum 0321

Leaf storey	Tillering (4.VI)			Culming (15.VI)			Blooming (11.VII)		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
1	288	316	7.4	—	—	—	—	—	—
2	325	365	8.6	—	—	—	—	—	—
3	412	450	9.3	—	—	—	—	—	—
4	506	525	9.6	387	437	8.0	—	—	—
5	—	—	—	415	516	8.5	—	—	—
6	—	—	—	407	471	9.4	—	—	—
7	—	—	—	378	412	9.0	275	331	8.6
8	—	—	—	354	426	8.8	222	257	8.5
9	—	—	—	—	—	—	198	221	8.0
10	—	—	—	—	—	—	167	203	7.4

The data contained in the table show that the moisture content in the leaves, their water-absorbing capacity (water-holding capacity) and hydrophily of dry matter vary harmoniously in the course of ontogenesis, clearly obeying a common rule.

At the phase of tillering moisture content, water-holding capacity and hydrophily of the dry matter of the leaves have ascending gradients in both varieties of wheat. At this period the upper leaves differ from the lower ones in having sharply increased indices.

At the culming phase the indices of water regime have at first an ascending gradient in the leaf series; after the maximum is attained (in early *Lutescens* 062 in the 4th storey, in the later maturing *Milturum* 0321, in the 5th storey) the gradient becomes a descending one. At this period the differences between the leaves of different storeys are less clearly pronounced.

At the earing or blooming phase all the indices of the moisture regime show a descending gradient. The upper leaves again differ sharply from the lower ones, but instead of having higher indices they have lower ones.

Such a type of variation is in accord with the theory of cyclic senescence of the plants and depends on the fact that the leaf metameric series is represented at any given developmental moment by organs possessing different age (of different degree of ontogenetic senescence), and passing different phases of their own developmental cycles.

Conclusions

1. Moisture content, moisture-holding capacity (moisture-absorbing capacity) and hydrophily of the dry matter of the leaf blades of wheat plants vary in the course of ontogeny according to Krenke's law which has been established for morphological characters.

2. At early developmental stages the indices listed above vary in the subsequent leaf stories of the metameric series in the ascending direction, *i. e.* they increase from the lower storeys towards the upper ones. At later developmental stages they vary in a descending order, *i. e.* they become smaller from the lower storeys toward the upper ones.

Karaganda Agricultural
Experiment Station.

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EXPERIMENTAL MORPHOLOGY

TRANSFORMATION AND PROLIFERATION OF ELEMENTS OF THE EYE LENS IN TISSUE CULTURES

By J. A. VINNIKOV

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The nature of the tissue of the lens and of the derivatives of other placodes participating in the formation of a number of sense organs cannot yet be considered as being determined. It is not yet clear whether these placodes, and the lens in particular, should be regarded as a part of the specific neural substratum of the sense organs, or, on the contrary, as less differentiated epidermal derivatives. After the retinal linings of the eye cup which sometimes showed genetic relation to the lens had been experimentally studied ([1-4]), it became possible to study the tissue elements of the lens and to answer this question. Experiments involving explantation of parts of the lens were carried out along with the study of the original material.

Investigated were lenses taken from the following animals or embryos: chick embryos, not under 24 hours of incubation and up to hatching; chicken, no more than 15 days old; rabbit embryos, from 12 to 22 days; newborn rabbits, up to 10—15 days; pig and cow embryos, of different ages; amphibian embryos (axolotl and *Rana temporaria*), from the early neurula stage and later on.

Very interesting cytological pictures could be observed during the transformation of the cells of the lens into differentiated fibres. Among the latter there are usually recognized central fibres located in the centre of the lens and going off the cambial zone of the lens ([7-8]); intermediate and young, located near the equator. This distribution of the fibres causes a strict and accurate spatial geometrical relation between the lens elements located beneath the capsula. It appears to be regulated by the exact mitotic cambial rhythm, cell turgor, and the limiting influence of the capsula. As the fibres grow longer, the nuclei of young and intermediate fibres become oval in shape. In preparations fixed with osmic acid the cytoplasm shows very fine fibrous structures extending plasm along the cell poles. At the same time these elements become argentophilic ([9]) and impregnated in the same way as Müller's fibres located close to them in the retina. It should be noticed that along with the differentiation described, all the lens elements, taking on a definite form, assume also a peculiar organization of the protoplasm and nucleus, which makes them entirely transparent. This phenomenon is probably connected with the peculiar structure of the proteins of the cells of the lens which are known to contain globulin-crystalline.

The preparation of explants involved the cutting of lenses into parts and freeing the lens fibres from the capsula. It was thus possible to make some observations on the living material. When isolated or arranged in the form of a complex lens the fibres are soon deprived of their regular hexahedral

prismatic shape, they swell, showing a change in the turgor of the protoplasm, which in the undamaged lens is regulated by the pressure of the capsula.

When examined in passing light the fibres display a change in their size (turgor) which probably depends upon a peculiar refraction of light rays in each of them. Each fibre is covered with a thin envelope strongly refracting light. When the fibre is damaged, the envelope is wrinkled forming a number of folds. The content of the fibre partly flow out in the form of droplets. The phenomenon proceeds very quickly in water, slower in Tyrode's solution; in an explantation medium consisting of a chick or rabbit heparinized plasm with embryonic extract from 8-12-day-old chich embryos it takes about 2—4 days. At the same time the fibres become intensely vacuolized and granulated, the processes spreading from the injured point inwards the fibre body. Besides, the fibrillar structures inside the fibres injured become clearly observable. The nuclear structures are fairly well seen. Thus, the «ascending» degeneration of the lens fibres results in the appearance of invisible structures which make the explanted lens fragments look opalescent. The elements of the lens become opaque (paranecrosis?) [10]. The capsula remains transparent all the time.

Both damaged and undamaged fibres are soon reduced in length; they lose their prismatic shape and transform into more or less regular spheres, often gigantic in size. This transformation is followed by their divergence. Owing to their close adjacency and adhesion when present in an intact organ, they mimic intercellular connexions which are soon broken. All the former fibres are gradually transforming into a sphere filled with very large granules which are continuously formed in the cytoplasm. When fixed these granules stain with eosin and become slightly darkened with osmium. The nuclei of these «spheres» usually adjoin the wall just like in the fat cells; they are surrounded by a small section of endoplasm. After 1, 2, 4, 6 days of explantation the «spheres» may burst, be destroyed, pouring out their contents, especially in the case where they originate from the central lens fibres of new-born rabbits and chicks. On the other hand, such inflated but not completely destroyed intermediate and young fibres, as well as part of the central fibres from the embryos are not destroyed but even pass the boundary of the original piece, and migrate to the surrounding fibrin. They partly retain their regular shape and granulated protoplasm; intensely multiplying by mitoses, they form the growing zone of the explant. As a rule, proliferation is especially active in explants descending from the equatorial zone of the lens. In these cultures it was possible to notice that the nuclear-endoplasmic central parts became free after the cover of the swollen lens fibres had been destroyed, and their granulated cytoplasm poured out. They were arranged into more or less regular rows, preserving at first the original orientation of lens fibres. The baroque outlines of intensely stained nucleus-containing endoplasmic remains of the lens fibres soon became regular. Along with the dark granules, part of which were prevalent here, thin fibres appeared in the protoplasm which gradually became clear. The nuclei increased in size. These elements intensely multiplied by mitosis and grew into the surrounding cytoplasm one by one or *en masse*, forming in the latter case cytoplasmic connexions with one another. The final stage of transformation of cultivated lens fibres is much similar to that described by me for Müller's fibres of the retina [4] proliferating *in vitro*, and explanted elements of the ependyme of the central nervous system [11, 12].

Of interest is also the ingrowing of parts of the lens from its proximal wall which is represented by a layer of cubic elements closely adjoining one another. Naturally, they show a less complicated cycle of transformation. Sometimes it was possible to observe the formation of lens fibres *in vitro* from the cambial zone of the lens. But the new-formed fibres soon lost their mutual connexion, apparently because of the absence of the capsula, assuming the shape of the «spheres» described above; their ultimate destiny was similar to the one described above, too.

The parts of the presumptive amphibian and bird lens rudiments were cultivated in a fluid explantation medium [13], inside epidermal sacks. It was not possible to isolate the rudiment without the neighbouring epidermal ectoderm. Under the epithelial lining there arose lens vesicles varying in degree of differentiation. In birds the lens, when explanted together with the retina, gave rise to similar proliferation. On the other hand, in amphibians the lenses arose regularly from the border of the eye-cup when the presumptive eye rudiment was explanted [13].

Further transformations of the lens explants resulted in the formation of an extensive zone of growth spreading over fibrinous substratum, mica, and often over the remains of the lens capsula and threads of Zinn's ligament. No epithelization of the explants by lens elements could ever be observed. The structures of the growing zone showed a striking similarity to those described for the retinal linings of the eye-cup and of the iris [1-4]. The outlines of the growing zone are highly variable. Surrounding the original piece in the form of a more or less regular aureole it looked like a flat membrane sharply outlined at the edges or loose at the periphery. The growing zone was often represented by extensive membranes located at the opposite poles of the explants, and looking like wings of a butterfly. In addition, strands of various form, star-like structures, *etc.*, were present there. The structures of the growing zone differed from one another in thickness, density and number of elements composing them. Parts of it were occasionally broken off the original piece and existed independently as peculiar complexes or isolated elements, often multinuclear. In fixed preparations in the cells of the growing zone, which are often characterized by elongated shape and a general longitudinal orientation, there was often observable a thin fibrillary structure which has more than once been described for the neural (glial) derivatives *in vitro*. Moreover, in the elements of the growing zone there could for a long time be observed dark granules. These granules were remains of the granulosity of the disintegrated matter of the original lens fibres, probably proteinic in nature. In the middle of the period of cultivation the cells, gradually becoming free of these granules, were getting more and more transparent. However, no tests have as yet been invented that would show whether the transparency of the elements in the growing zone was or was not identical with that of the lens fibres when these are present in an intact lens [14-16].

Towards the 20—30—40th days of cultivation, as reinoculations and cutting-out of new explants were repeated, the remains of the original piece disappeared entirely. The cultures assumed their characteristic features peculiar to stationary lens culture of typical glial type [17-18]. It should be pointed out that the considerable proliferation power of the lens fibres is always to be kept in mind when one has to deal with any kind of growth in the eye, either of traumatic, or blastomogenic origin.

The experimental material obtained allows us definitely to reject the epithelial (epidermal) interpretation of the histological nature of the lens. From their genesis, structure, and cycle of transformations under experimental conditions the cellular elements of the eye lens should be identified [18] with the glia of the central nervous system, *i. e.* with Müller's fibres of the retina and the linings of the iris, ciliar processes, and tapetum. It is to be noticed that alongside of the ependyme of the eye-cup [5-6] the embryonic spinal cord and cerebrum [13] and, as well-known, the presumptive epidermal ectoderm [20] as a whole are capable to transform into a lens. The lens is only a part of the whole system of the eye-cup, and together with the latter (*i. e.* with the central nervous system and other derivates of the placodes) it is to be regarded as a highly differentiated ectodermal (neural) derivative controlled by the same histogenetic principles both *in vivo* and *in vitro*.

Some indirect biochemical data which revealed a high concentration of glycogen, carboanhydrase and vitamin C both in the lens and in the retina are also speaking in favour of the point of view above advocated. These

observations make it possible to suggest the similarity in the metabolism responsible for the structure and function of the two organs here considered. Observations made on the changes in the turgor of the lens fibres make it possible to admit their specific reactivity, particularly with respect to light rays, which are refracted and concentrated in a definite point of the lens. The possibility is not excluded that accomodation is sensitized by the excitability of the lens fibres. If this suggestion be adopted, then on the basis of the facts considered above, the neural (glial) nature of its morphological substratum as well as a definite independent rôle played in the receptive function of the eye seem to be quite probable.

Institute of Neurology.
Academy of Medical Sciences of the USSR

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EXPERIMENTAL MORPHOLOGY

REGULATION POWER OF THE CAUDAL BUD IN *RANA TEMPORARIA* EMBRYOS

By M. A. WORONZOVA and L. D. LIOSNER

(Communicated by I. I. Schmalhausen, Member of the Academy, 29. I. 1946)

In 1931 Vogt (1) described his experiments on the amputation of the caudal bud in *Urodela* and *Anura* embryos. He found that the operation in question resulted in the development of tails, the distal part of which showed indelible defects, or was absent at all. If, however, the same operation wes made on adult embryos in which the caudal bud had already developad into a tail, typical regeneration took place, leading to the development of a normal tail. According to thorough observations made by Svetlov (2), embryos of *Rana temporaria* were also found incapable of tail regeneration when operated at early stages of the caudal bud, and showed tail regeneration if the operation was practised with adult embryos. On the basis of thees observations both authors made far going conclusions. Vogt believed that regeneration power arises at a definite stage of development only. The oppesite conclusion arrived at by Svetlov was that regeneration ability exists throughout the development, being, however, suppressed by inhibitory agents at the time of formation of bud rudiment. At this stage the processes of development are so intense as to cause suppression of regeneration.

In the spring of 1944 and 1945 we repeated the experiments involving the amputation of the caudal bud and accumulated extensive experimental data which did not only complete those of Svetlov and Vogt, but also went to shed new light on the problem as a whole and its general interpretation. Since the problem as to the existence of regeneration at early development stages is a matter of dispute, a more general term, namely that of regulation, will be used in the subsequent.

Following Svetlov's scheme of divison into stages, it is necessary to note that the question about the regulation power of the caudal bud at the first and second stages of development is of great importance. At these stages the caudal bud has not yet been differentiated and represents a small tubercle whose length and width are equal. Amputation of the caudal bud at the first and second stages of development resulted in our experiments in the formation of deficient tails. However, aside from these, quite normal tails were also found to occur, although in a smaller number of cases. In distinction from Svetlov, we did not find any significant difference in the experiments in which operated embryos were at the first or second stages, although the number of embryos used was no less than 1000 in each set. It should be pointed out that the long period during which the operated embryos were under observation was a characteristic feature of our experiments. It could be found out

with absolute clarity that in some of the embryos the defects were gradually disappearing. Some of the embryos were found to show small defects, while the other had quite normal tails.

By increasing the number of experiments and varying the methods applied (3—4 stages) we also succeeded in adding precision to the data of earlier authors with respect to the regulation in embryos of later stages of development.

At this stage the caudal bud is greatly extended in length and undergoing differentiation. The difference between the regulation power of the tail bud in embryos of the first and the second stages, on the one hand, and those of the third and fourth stages, on the other, was found to be no very important one, and quantitative rather than qualitative in nature. Indeed, in a small per cent of cases the amputation of the caudal bud made at late stages of development is followed by the formation of deficient tails. The frequency of the latter was especially high when instead of the whole bud only the upper part of it was removed. This operation is followed by a strong depression of regulation, and from 30 to 50 per cent of the embryos developed deficient tails. We were also successful in showing that regulation power was greatly dependent upon the level of long axis of the tail bud at which the amputation was carried out. The more distally passed the level of amputation, the higher was the per cent of normal tails developed.

Thus, the difference in the regulation of the amputated tail bud is that a higher per cent of defective tails is developed when the operation is made at early stages of development. The relation is reverse if the operation is carried out at the later stages. Besides, tail defects, if any are formed, are usually larger in size in younger embryos.

From the experiments shortly outlined above the conclusion can be drawn that any embryo, including the youngest one, is capable of regulation. This statement, formulated by Svetlov in a somewhat different way, is no longer a hypothesis and may be considered now as experimentally proved. However, we understand it in somewhat different way. Svetlov believes that at some stages of development regulation ability cannot be realized, being influenced upon by the action of inhibiting factors. On the basis of our experimental results we assert that regulation power may be revealed in some animals and may not in the other in spite of lack in their age difference. There are reasons to believe that the animal in which bud amputation led to formation of defective tail is also possessing the regulation power but cannot realise it because of some unknown causes. Experimental animals forming on amputation defective tails develop approximately in the same ways as compared to those capable of perfect regulation. Therefore, the suggestion of Svetlov about the inhibiting action of the intensive processes of development on the process of regulation is scarcely probable.

Vogt's interpretation of the phenomenon under consideration also needs essential corrections. This author believes that regeneration of the tail becomes possible after a definite stage has been reached. He does not regard the processes of regulation taking place in the early development and leading to some reducting of defect as true regeneration. According to Vogt, the peculiarity characteristic of regeneration is the formation of blastema, *i. e.* the presence of proliferation. He believes that at the early stages of development only the morphallaxis, *i. e.* recombination of the cells, is taking place.

It is true in the considerations presented above that the processes of regulation may proceed in different way in the animals of different age. In particular, the morphallaxis is predominant early in development, while the epimorphosis (proliferation) is the more usual method of regulation at the later stages of development. However, the presence of proliferation can hardly be regarded as a feature characteristic of regeneration. It is usually observed that both are intimately interacting with each other in the same processes. In addition, epimorphosis was not found to present in a num-

ber of cases of typical regeneration. On the contrary, they were characterized by the presence of morphallaxis.

Finally, on the basis of this criterion, the data of histological investigation of regulation available are far from being sufficient to assert as to whether or not the process of regeneration is taking place in any given case. We believe that the feature characteristic of regeneration is the formation of the pre-existing organ or a part of the organism previously removed. It is a sharp manifestation of the repeated character of the regeneration development. Since the embryonic development being once broken, there apparently takes place no recurrence to the conditions characteristic of the stage at which the amputation had been made, the term regeneration cannot be used in respect to the phenomena under consideration. Regeneration can be spoken of only in respect to organisms which have reached at more or less stable condition (larval or adult).

Thus, if one can regard that regeneration power does arise during ontogenesis, it must be understood in a sense quite different from that of Vogt.

As to the regulation power resulting in the normal tail development from the injured tail bud, it is peculiar to each embryo from the very beginning but does not arise during ontogenesis. Manifestation of this regulation power is highly variable in different individuals according to a number of factors. Therefore, individual variation exceeds the difference in the course of regulation at different stages of development.

The Second Moscow Medical Institute.

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ZOOLOGY

ON GEOGRAPHICAL VARIABILITY IN *COREGONUS MUKSUN* (PALLAS)

By M. I. MENSHIKOV

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Many species of the genus *Coregonus* are known to be highly plastic and some of them have formed many distinct forms. But in *Coregonus muksun* only one species (*C. muksun*) has so far been distinguished which is confined to the freshened parts of the Polar Sea and the lower reaches of Siberian rivers, from the Ob to the Kolyma; one subspecies (*C. m. aspius*), from the lakes of the basins of the Gulf of Bothnia and the Gulf of Finland, and one morpha (*C. m. m. lacustris*), from the system of the Piassina River (2). Such a scarcity of local forms should be put down to a general lack of knowledge about this species, especially its typical form from the Ob, rather than to a lack of plasticity. We have investigated the taxonomic characters of 100 muksun specimens (52 males and 48 females) collected in the Lower Ob at the Peregrebin and Salekhard hatcheries. The investigation was carried out according to the scheme of Smitt medified by Pravdin (10), and the results obtained were compared with literary data on the taxonomy of the muksun from other Siberian rivers. We discovered geographic variability of several meristic (Table 1) and plastic (Table 2) characters and thus were able to establish some new local forms. We could likewise determine the degree of age variation in the taxonomic characters investigated. In the tables are shown only such characters whose coefficients

$$M_{\text{diff}}\left(\frac{M_1-M_2}{\sqrt{m_1^2+m_2^2}}\right)$$

are higher than 3 (meristic characters) and 6 (plastic characters).

Only the Yenissei and the Pjassina muksuns differ from the muksun of the Ob in respect to the number of scales on the lateral line, the two former having higher extreme values of this character than all the other forms compared. The number of gill-rakers on the first gill-arch is a far more variable character, having a tendency to geographic variability: both the extreme and the mean values of this character increase from west to east. The muksun of the Lena is an exception to this rule, as shown, especially, by the data of Sych-Averinzeva. The number of gill-rakers in a fish of a body length of 39 to 60 cm remains almost unchanged with growth. However, Sych-Averinzeva was working mainly with young fishes, so that the mean values have been somewhat reduced by the effect of age variation. The results of Borisov who investigated adult muksuns from the Lena show a higher value of this character. The muksuns from all the basins investigated were found to vary greatly in this respect, the lacustrine form having the highest number of gill-rakers.

The Ob muksun differs from the Gydan and Lena muksuns in the number of branched rays in the anal fin.

Table 1

Relative Variation of Meristic Characters in *Coregonus muksun*

Basin	n	Number of scales in the lateral line		Gill-rakers		Branched rays in A	
		variations	$M \pm m$	variations	$M \pm m$	variations	$M \pm m$
Ob	100	84 100	91.73±0.35	42 56	48.80±0.31	11 14	12.63±0.7
Gydansk Gulf (5)	30	83—101	89. 9±1.19*	42—60	50.8 ±0.48	10—14	11.8 ±0.02
Yenissei (8) . .	169	85—102	93.36±0.25	49—64	54.78±0.26	—	—
Yenissei (7) . .	37	86—108	-	48—62	55.65±0.55	11 14	—
Piassina (9) . .	28	88—107	93.5	44—65	56.04	—	—
Norilsk lakes (9)	28	82—98	92.0	45—72	59.5	—	—
Norilsk lakes (3)	47	83—100	91.7	45—78	64.4**	—	—
Lena (4) *** . .	27	85—99	92.76±0.66	47—63	54.54±0.62	10—13	11.74±0.12
Lena (11) . . .	76	84—92	91.16±0.38	45—62	52.26±0.32	10—14	11.55±0.09

* This average was computed by Essipov (5) on 14 fishes.

** Belykh (1) who investigated Norilsk muksun from lake Lama found the number of gill-rakers to be 41—79 with an average of 59.60.

*** The mean values for the Lena muksun were computed by Sych-Averinzeva according to the material of Borisov (4).

As regards the meristic characters not included in Table 1, there are differences in the number of rows of scales above and below the lateral line (between the Ob and the Lena muksuns; $M = 11.53$ in the first, and 10.37 in the second); in the number of simple rays in the anal fin (between the Ob muksun and the muksun of Gydan and Lena; in the first $M = 4.02$) and in the total number of rays (both branched and single) in the pectorals (between the Ob and the Gydan and Lena muksun; in the first $M = 15.95$) and in the ventrals (between the Ob and the Lena muksuns; in the first $M = 12.29$). All these characters show a slight decrease of mean values from west to east.

The Ob muksun is distinguished from the muksun of the Gydansk Gulf by a greater postorbital part of the head and a broader forehead. The width of the forehead equals the length of the upper jaw and exceeds the length of the snout. The Ob muksun differs from that of the Lena by the length of the caudal peduncle, the base of A, snout, the diameter of the eye, the antedorsal space and the height of the body. From the Lena muksun it differs in the length of the caudal peduncle, the base of A, the distance $V-A$, snout, upper jaw and the diameter of the eye. The muksun of the Gydansk Gulf differs from the Yenissei muksun in the length of the snout and the base of A, whereas the Lena muksun has a greater body height, distance $V-A$ and a longer snout. The last character decreases somewhat with growth, so that it could be expected to be lower in the Yenissei fishes which are bigger than those of the Lena; however, it proved to be higher, and this seems to indicate that the difference observed is not one of age variation. The same holds true of the Gydan and Ob muksuns.

As regards the muksun of the Pjassina River, data are available for four plastic characters only (9). The greatest height of the body is 21.5 per cent of its length, which is less than in all other forms compared.

The differences mentioned are related to such characters as do but little change with growth, if at all. In general with a body length of 39 to 60 cm the effect of age variation is more or less marked in a few characters only,

Table 2

Relative Variation of Plastic Characters in *Coregonus muksun*

Character	Ob, $n=100$ variation	Ob, $n=100$ $M \pm m$	Gydansk-Gulf, $n=14$ $M \pm m$	Yenissei, $n=37$ M	Lena $n=27$ $M \pm m$
Body length (according to Smitt)	39—60	52.4	30—50	45-62	50.4
Percentage of body length:					
Greatest height of body	21—28	24.25±0.14	23.0±0.46	22.6	24.7
Antedorsal distance . .	38—45	41.40±0.09	41.9±0.65	42.9	42.03
Distance $V—A$	24.0—27.5	25.70±0.08	26.7±0.42	25.4	27.15±0.16
Length of caudal peduncle	10.5—14.0	12.01±0.07	—	13.9	13.92±0.12
Length of base of A . .	9.5—13.0	11.53±0.07	11.3±0.22	10.2	10.48±0.10
Percentage of length of the head:					
Length of the snout . .	22—30	27.02±0.16	26.9±0.57	29.2	24.76±0.25
Diameter of the eye . .	14.0—18.5	16.19±0.11	17.1±0.39	14.3	14.82±0.19
Postorbital part of head	57—64	59.99±0.16	55.0±0.69	—	—
Length of upper jaw . .	25—32	29.03±0.14	29.3±0.55	—	26.82±0.25
Width of forehead . .	25—34	29.29±0.16	26.7±0.36	—	28.3
Percentage of central part of head:					
Length of head	32—41	37.08±0.20	37.1	—	—
Width of forehead . .	36—44	40.01±0.20	34.9	—	—

* The biometrical values of the characters of the Lena muksun were computed according to the table of indices given by Borisov.

such as the height of the fins, and the ratios of different parts of the head which are correlated with growth by a negative correlation. The coefficients of correlation r computed for 100 fishes were as follows: number of scales in the lateral line, 0.07; number of gill-rakers, 0.07. In per cent to body length: length of head, 0.43; length of the central part of the head, 0.40; greatest height of the body, 0.11; antedorsal space, 0.11; distance $V—A$, 0.02; length of caudal peduncle, 0.18; height of the dorsal fin, 0.63; length of the base of the anal fin, 0.19; height of the anal fin, 0.38. In per cent to length of the head: postorbital space of the head, 0.10; width of forehead, 0.01; horizontal diameter of the eye, 0.33; length of snout, 0.20; and length of the upper jaw, 0.12. All the muksun specimens investigated proved almost identical in respect to length; thus, the differences observed cannot possibly be caused by age variation, even in such characters as the diameter of the eye, for which a relatively high coefficient of correlation was obtained. A possible effect of sex dimorphism should also be excluded, since all the material compared showed an almost equal sex-ratio.

The muksuns described above displayed biological differences as well. Thus, the Ob muksun is a freshwater-semianadromous fish, unlike the Gydan and Lena fishes which are semianadromous. The former has also a higher rate of growth and reaches sex maturity two or three years earlier than the latter two. Thus, it can be concluded that in the Gydansk Gulf and in the rivers Yenissei, Piassina and Lena muksun is represented by local forms differing from the typical Ob form both morphologically and biologically.

As regards the European subspecies *C. m. aspius*, it differs from the typical form in a few characters, judging from the literary data available. The difference referred to above in the number of gill-rakers ([2]) has not been observed: according to Pravdin ([9]), this subspecies has on the average 48 gill-rakers, as compared with 48.8 in the typical form. Neither could we observe any difference in the number of vertebrae and in the number of scales in the lateral line. Some differences may possibly exist in the length of the gill filaments (in the subspecies they are shorter than the gill-rakers, while in the typical form the filaments are usually longer), in the height of the body (which is greater in the typical form) and in the diameter of the eye which is by far greater in the subspecies; however, in the latter this character was measured only on small specimens, so that in this case the difference may have been due to age variation.

Molotov State University.

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ZOOLOGY

ANCESTORS OF THE BAIKAL *COTTOIDEI* IN ZIPO-ZIPIKAN LAKES (VITIM-RIVER SYSTEM, BASIN OF THE LENA)

By D. N. TALIEV

(Communicated by I. I. Schmalhausen, Member of the Academy, 15. XII. 1945)

In October 1945 I obtained from professor M. M. Kozhov several sculpins collected in 1939 by the expedition of the Bio-Geographical Institute at the University of Irkutsk sent to the Zipo-Zipikan Lakes (Baunt, Bussani, Oron,

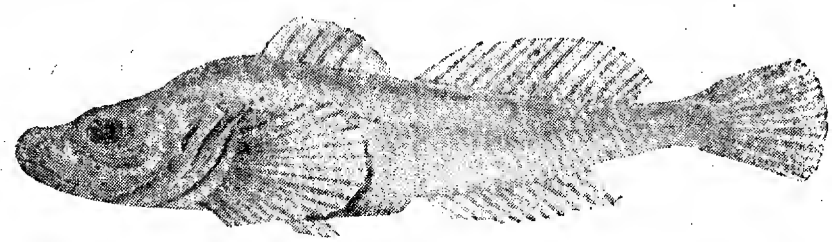

Fig. 1. *Limnocottus kožovi*. Lake Baunt (system of the river Vitim). 1 : 1.

Maloje Kopyluchi and others) situated on the river Zipa, a tributary of the Vitim, within the boundaries of the Buryat-Mongol ASSR*. The expedition was headed by F. B. Mukhomediarov.

Among the material received have been discovered a new species of *Cottoidei* from the Baikal endemic family *Cottocomephoridae*, two Baikal endemic species of the family *Cottidae* (one of them proved to be a new subspecies) and *Cottus sibiricus* Kessler, widely distributed in Siberia.

Fam. *COTTOCOMEPHORIDAE*

Gen. *Limnocottus*

Limnocottus kožovi nov. sp. (Fig. 1), lake Baunt, July, 1939, F. Mukhomediarov, 1♀, DVII; A 13; P 17; V 1—4; C 7—1—10—1—5; l. l. 20?

Greatest body height in per cent to absolute body length, 18.4 per cent; least body height, 6.2; length of the caudal peduncle, 16.7; length of the base of D_I, 14.9; length of the base of D_{II}, 27.8; length of the base of A, 20.4; antedorsal space, 31.8; length of P, 19.2; length of V, 11.5; length of the head, 27.2. Postorbitral space in per cent to length of the head, 46.1; width of the head, 80.6; diameter of the eye, 15.9; width of the forehead, 19.4;

* I am greatly indebted to Professor M. M. Kozhov for this highly interesting material.

length of the snout, 29.6; height of the head, 57.7. Postcleithrum represented by a single small upper bone. Postorbitalia reduced. Teeth in the jaws and on the vomer. Space between the gills narrow, forming a small fold at the point of attachment. The lateral line terminates at a distance from the caudal fin; its anterior part consists of several rows with openings far larger than in the Baikal species of *Limnocottus*: continued on the head, likewise in the form of larger spores. Body covered with spines only below the pectorals. The ventrals do not reach the vent. There is one strong spine on the preoperculum and three feeble spines below it, hidden beneath the skin. The rims of the eye sockets are rather salient, the frontal bones protrude over the eyes, the infraorbital bones form a ridge under the eyes. A tubercle on the snout. Two slight longitudinal ridges on the nape and, on the lateral side of each of them, one more ridge which can be felt, but hardly seen. The back is abruptly separated from the neck by a steep rise. Length—104 mm.

The new species is closely related to *Limnocottus megalops* Gratz and in its general appearance resembles the sculpins of the genus *Asprocottus* related to

Fig. 2. *Cottus kessleri bauntovi*. Lake Baunt (system of the river Vitim). 4 : 3.

Limnocottus (11). The presence of reducing ridges on the nape and the character of the spines on the preoperculum permits also of a comparison with the Amur *Mesocottus haitej* (Dyb.) and the Japano-Chinese *Trachidermus fasciatus* Heckel.

Fam. *COTTIDAE*

Gen. *Cottus* Linné

Cottus kessleri bauntovi nov. subsp. (Fig. 2). Lake Baunt off cape Feligonov, seine, July 1939, F. B. Mukhomediarov, 3 sp. (2♀, 1♂). D VI—VII, 19; A 18—20; P 16—17; V—1—4; C 7—9—1—10—1—5—7; l. l. 39—40.

The greatest body height in per cent to absolute body length 15.1—15.9 per cent; the least height, 4.2—4.6; length of the caudal peduncle, 9.4—8.0; length of the base of D_I, 12.4—14.6; length of the base of D_{II}, 27.5—29.7; length of the base of A, 34.1—34.7; antedorsal space, 29.8—31.8; length of P, 22.3—24.2; length of V, 13.2—14.0; distance between D_I and D_{II}, 4.5—5.4; length of the head, 22.6—24.7. Postorbital space in per cent to length of head, 46.4—48.2 per cent; width of head, 95.0—95.3; eye diameter, 17.5—17.6; width of forehead, 14.4—17.5; length of snout, 37.0—37.4; height of head, 54.0—54.1.

The body is completely naked (even without skin tubercles), the lateral line extends to the base of the caudal fin; the ventrals do not reach the vent. The sides of the body are covered with irregular dark spots forming four cross bands. The body is somewhat shorter and thicker than in the typical form. The postcleithrum is represented by two well developed bones. Teeth in the jaws and on the vomer. Length up to 98 mm. The main points of difference between the form described and the typical are: shortened anal and first dorsal fins; a smaller number of rays in the caudal and pectoral fins, the presence of a gap between D_I and D_{II}, an entirely naked, shortened and thickened body.

The new subspecies is much closer allied to the representatives of the genus *Cottus*, common in the Palaearctic, than to the typical form, which has become specialized and is now (10) in the process of transition to a bentho-pelagic mode of life.

Besides the new forms from the Baikal *Cottoidei* described above, in lake Baunt was found *Cottus kneri* Dyb. (lake Baunt, off cape Feligonov, seine, July 1939, F. B. Mukhomediarov, 2 spec. (1 ♀ and 1 ♂)). The formula of these sculpins is similar to that of the typical *C. kneri* from lake Baikal, though their body is somewhat more elongated. Typical *C. kneri* have a much deeper body than other representatives of the genus *Cottus* of the Palaearctic, so that *C. kaganowskii* Berg. from the river Anadyr (3), the nearest related to *C. kneri*, has more affinity with *C. kneri* from lake Baunt than with the Baikal *C. kneri*.

Besides the forms mentioned there have also been found some specimens of *C. sibiricus* Kessler (lake Baunt, seine, July—September 1939, F. Mukhomediarov, 4 sp.). All the sculpins are rare in lake Baunt. These specimens were caught inshore. There is no record of sculpins from other lakes of the Zipo-Zipikan system.

Representatives of the Baikal endemic fauna have been known before to occur in the Zipo-Zipikan lakes. Thus, Kozhov (5,6) has recently discovered there a Baikal polychaet *Manajunkia baicalensis* Nussb. Judging from the geomorphology of the Zipo-Zipikan depression, Kozhov thinks that the lakes of this region are remnants of an ancient giant lake which covered an area of several thousand km². This ancient lake was probably connected with Baikal, forming a link of the ancient Baikal lacustrine system. The Baikal polychaet has probably remained there from those times. This viewpoint is strongly supported by the occurrence in lake Baunt of Baikal *Cottoidei*; indeed, if because of its wide distribution in the river N. Angara and the lagunes of the Baikal *M. baicalensis* can be regarded as a relatively eutropic form, the Baikal sculpins of the genus *Limnocottus* should be considered strictly stenotopic. They inhabit exclusively the open parts of lake Baikal, so that their penetration through any river discharge is quite out of question. As to the penetration of Baikal *Cottidae* from the Baikal into the Zipo-Zipikan region, this seems impossible under the conditions of the modern hydrographical net, either.

Though *C. kneri* has been reported from the Yenissei and even from the Nizhnaya Tunguska, it penetrated there along the river N. Angara and, as regards its spreading from the Baikal into its tributaries, this is limited by some few kilometres. The immigration of *C. kessleri* from the Baikal to its tributaries is far more extensive. They are widely distributed in the basin of the Selenga River and have even penetrated into the system of Arakhleyan lakes, through the river Khilok. However, they do not occur in those lakes of this system which are drained not by the Selenga, but by the Vitim (lake Ivan and lake Tassei) (12). Besides, all the specimens of *C. kessleri* which had been caught outside the Baikal, were found to be typical representatives of this species, with all the characters impressed by a bentho-pelagic mode of life. Therefore the subspecies *C. kessleri* described above could not possibly have originated from these forms which are presently settling down. Neither is it possible to consider, according to Berg (2), the Baikal *Cottoidei* in lake Baunt as remnants of a widely distributed freshwater neogene fauna of Eurasia, which died out ewerywhere except for some few places, since *L. kožovi* has many features common with the Amur *M. haitej* and the Japano-Chinese *T. fasciatus*, which takes its origin from the marine *Cottidae* (1). If this is so, then the Baikal elements of the Zipo-Zipikan lakes should be considered as remnants of a fauna from which certain groups of Baikal endemics have later been formed. This assumption is further supported by the relationship between *L. kožovi* and the Far-Eastern *Cottidae*, as well as the greater affinity

existing between C. *kessleri bauntori* and the representatives of the genus *Cottus* of the Palaearctic as compared with the typical *C. kessleri*. The penetration of Far-Eastern forms into the Zipo-Zipikan region has undoubtedly taken place, since in these lakes has lately been discovered an isopod (*Asellus hildendorfii* Bov.) whose distribution is restricted entirely to Far-Eastern waters. This isopod is not known from other sections of the Lena basin and Siberia (7). Presniakov admits (9) that representatives of the Far-Eastern fauna may have come to this region; he writes (p. 396): «Finally, there remains the question as to the communication with inland seas of Central Asia, which could have been successively connected with the west (Sarmatian Sea) or the east (East Chinese Sea). Since the rivers which flow into the Polar Sea and the Pacific Ocean (Irtysh, Yenissei, Selenga and Amur) are draining the inland depression by their upper reaches and tributaries, the penetration of fauna along these waterways seems quite possible». A further approach to the problem of the ways of penetration of Far-Eastern fauna into the Zipo-Zipikan lakes is gained from a suggestion made by Kotulsky (8), recently developed by Kozhov (7). According to Kotulsky, the ancient Zipikan lake was drained during the Tertiary or the Quaternary not by the Lena as nowadays, but by the basin of the Amur River. Such an essential change in the orography of the Transbaikal may have been due to an upheaval of the whole land, reconstructing the river net in the mid-channel of the present Vitim. Thus, we see that the occurrence of a fauna of Far-Eastern origin in the Zipo-Zipikan region is not inconsistent with geological data. As regards the presence of primitive forms of the Baikal *Cottoidei* described above, which take their origin from the Pacific basin, it confirms our hypothesis as to the origin of certain groups of Baikal *Cottoidei*, advanced as early as in 1938 on the basis of serological analyses of these forms (11). We suggested that the Baikal *Cottoidei* from the genera *Limnocottus* and *Asprocottus* have a common ancestor allied on one hand to *L. megalops* Gratz. and on the other, to *A. herzensteini* Berg., which was derived from brackwater *Cottidae* of Far-Eastern seas. During the late Tertiary they may have penetrated along the rivers in the lakes, from where later on was formed the fauna of the modern Baikal. We suggested, too, that *C. kneri* and *C. kessleri* are derived from Far-Eastern forms, *C. kessleri* being finally formed in the Baikal itself. The *Cottoidei* discovered in lake Baunt confirm in full all our former theoretical considerations. The opinion of V. Gratzianov (4) about the affinity of the Baikal *Asprocottus* to the Amur *Mesocottus* has been confirmed, too.

The Baikal Limnological Station.
Academy of Sciences of the USSR.

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ZOOLOGY

A NEW ENDEMIC FROM THE MOUNTAINS OF CENTRAL ASIA, *AGAMA PAWLOWSKII* SP. NOV. (*REPTILIA, SAURIA*)

By S. A. CHERNOV and V. B. DUBININ

(Communicated by E. N. Pavlovsky, Member of the Academy, 14. I. 1946)

The mountains of the south-eastern part of Central Asia are known to be inhabited by a number of endemic species of reptiles. The areas of distribution of these species extend scarcely if at all beyond the boundaries of the region of the mountains. To such species belong in the first place the Turkestanian agama (*Agama lehmanni* (Nik.)), and two lizard species, *Eremias nikolskii* Bedr. and the Tadjikian lizard, *Eremias regeli* Bedr. The existence of these endemic species makes us assume that the Turkestan highland was also a centre of origin of a peculiar herpeto-fauna. The correctness of this assumption is supported by a finding made by V. B. Dubinin in 1944 on the northern slope of the Turkestanian mountain range. This finding consisted in the spinal column of a lizard which belonged to an unknown species of the *Agama* genus. The finding was a rather unexpected one, and the more so as the *Agama* described below was a relatively big lizard, leading a diurnal mode of life. All this testifies once more to the poor state of knowledge of the herpetological fauna of the mountains of Central Asia.

The new species stands quite apart from all other species of the *Agama* genus, which are distributed over Central and Anterior Asia. A number of characters make us assign to it a position intermediate between the two groups of species which have been raised by certain authors to the rank of subgenera, while others even classed them as independent genera (*Stellio* and *Agama*, respectively). Thus, the lizard described has a large, open tympanic membrane, while the scale-covering over its tail does not form any transverse rings, the toes are flattened from the sides, the head relatively high, *etc*. According to its habitus, the presence of a jugular ridge, an increased occipital shield, the nature of the scale-covering of the body and partly of the tail, as well as some other characters, the new species approaches most closely the agamas of the group *Agama agama* (L.), which are widely distributed in tropical Africa, and are better known by the name of *Agama colonorum* (Daud.). The difference between the new species and *Agama agama* is quite conspicuous, however, as may be seen from the description given below.

The species has been named by us after E. N. Pavlovsky, Member of the Academy, whose name is closely associated with the study of the herpetological fauna of Central Asia.

Agama pawlowskii sp. nov.

Type No. 15637, belonging to the Zoological Institute of the Academy of Sciences of the USSR, ♂, locality: Khavast district of the Uzbek SSR, 15 km south of the village Julangar and 65 km south of the Ursatiev station of the Tashkent railway. Collected by V. B. Dubinin, 29.V.1944.

Body slightly flattened dorso-ventrally, tail laterally compressed, especially beginning with the second third of its length. Head relatively high: height 11.5 mm against a maximum breadth of 16.0 mm. The upper surface of the snout between nasal shields flat, or even slightly concave. Shields of the upper surface of the head with low but well pronounced, rather pointed and long ridges, better developed in the frontal region. 16 small shields are arranged across the head among the supercilial ones. The occipital shield (Fig. 1) is much larger than the surrounding ones. The intermaxillar shield broad but low, its breadth exceeding height 2.5 times; adjoined by 7 shields, aside from the superlabial ones. Nasal shield strongly inflated; tubular nostril located in its posterior part, under *canthus rostralis*. Between nasal and first superlabial shield is situated a single scale. Superlabial are 9—10 in number; they represent strongly increased lamellae, tightly adjoining one another

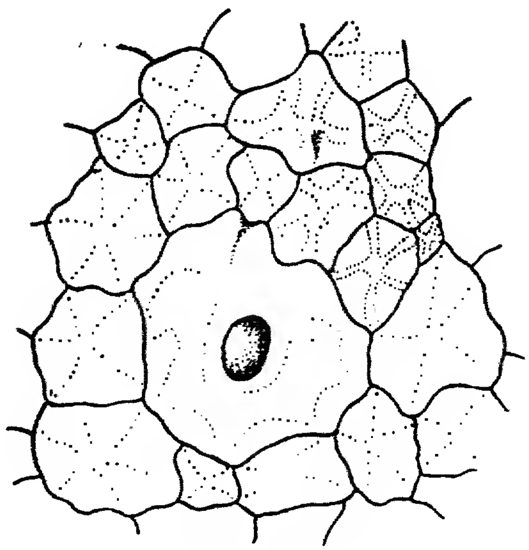

Fig. 1. Occipital shield with parietal eye. Magnified.

with straight, free edges. Tympanic membrane situated superficially; its large diameter equals the length of the slit between upper and lower eyelids.

Trunk covered with homogeneous, fine, rhomboidal, imbricated scales; abdominal and lateral scales somewhat finer than the dorsal ones; these covering the neck, much finer than the dorsal ones. The middle part of the body is encircled by 65—70 scales. Behind the aural aperture and on the sides of the neck are arranged groups of spine-like scales forming small tubercles: the spines of the 1—3 central scales of such a tubercle are the best developed. Dorsal and lateral scales with well-pronounced ridges (keels) whose free edges are turned up, forming small pointed spines; these ridges are directed posteriorly and towards the backbone. Abdominal scales with obtuse, low ridges, with ends forming no spines. The scales of the anterior part of the throat with well pronounced sharp ridges passing towards the middle of the throat into pointed, nearly vertical spicules. Dewlap, poorly developed. Along the neck, trunk and first half of tail passes a ridge of moderate height. On the neck it is formed of 8—9 almost vertical scales, strongly compressed from the sides (Fig. 2). On the back and tail this ridge is continued in the form of well developed, lateraly compressed small ridges of the medinal longitudinal row of scales, which are directed upwards and backwards. On the back the ridge

is lower than on the neck. At the base of the tail it is the same height as on the back.

It becomes appreciably higher towards the first third of the tail, after which it gradually diminishes in height again, and vanishes altogether in the posterior half of the tail. Caudal scales much coarser than dorsal ones, arranged in oblique rows. Beginning with the second fourth of the tail, the scales become elongated in shape. The caudal scales bear well pronounced though rather low ridges, whose free edges are garnished with small spicules.

The scales covering the thigh and the shank from above are somewhat coarser than the dorsal ones, but among the coarse scales there runs a longitu-

Fig. 2. Neck ridge, side view. Magnified.

dinal strip of finer scales; the scales are garnished with low but well-expressed ridges.

The toes are compressed from the sides. The fourth toes on the hind limb bear 2—3 plates from below; each of these bears two pairs of ridges, the middle of which is the best pronounced. Anal pores arranged into two rows; the row nearest to the cloacal opening consists of 13—14, the other, of 11—12 pores. Body length together with head (L) 83.5 mm, length of tail (L. cd.), 163.0 mm.

When alive, the animal is a dark, brown-olive colour, with indistinct dark-brown transversal stripes on the sides, tail and limbs. 5 lighter, yellowish spots are observable along the spinal column; the first of them, situated within the occipital region and in the anterior part of the neck, is elongated in shape; the last, fifth spot is located in the sacral region. Head, dark-brown. Trunk and tail, yellowish on the ventral side, bearing no spots. As soon as the animal is captured, the colour of its throat passes from light-yellow to bright greenish-blue; at the same time a plumbeous-black, marble-like pattern appears, which is most clearly pronounced along the edges of the mandibles.

A specimen fixed with alcohol shows no such pattern, its back being uniformly brown-grey, and the abdomen, light-grey in colour.

The lizard here described was caught on a slope of a stony canyon cutting a high ridge of the northern piedmont hills of the Turkestan mountain ridge, at a height of about 1300 m above sea level. The animal was resting on a branch of one of the caper shrubs (*Capparis spinosa*) that grew close to a talus.

Zoological Institute.
Academy of Sciences of the USSR.
Academy of War Medicine.

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